

Science Focus

FEED YOUR MIND

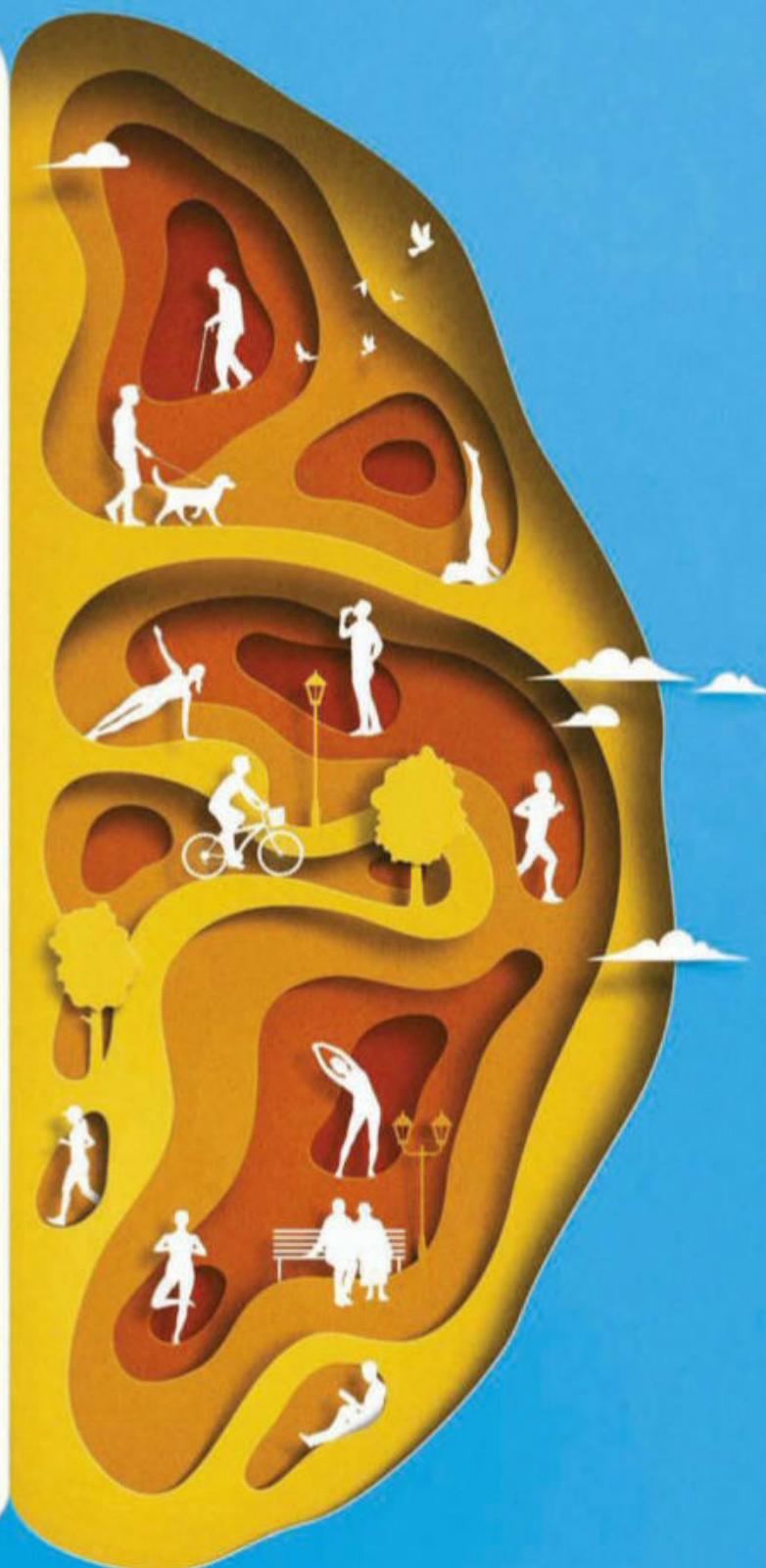
*The hunt for the
UNIVERSE'S FIRST GALAXIES*

*How to deal with
AIR POLLUTION*

*The value of
PLAYING VIDEO GAMES*

THE HIDDEN POWER OF THE BRAIN

Can you really think
yourself healthy?



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machines

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← What happened to the Haast's eagle? p81

FROM THE EDITOR



Here it is, your first issue of the new-look *BBC Science Focus*. What's changed? We listened to your feedback and have tried to give you more of what you love. As a result, *Discoveries* (p15) is bigger and better, providing more insight and analysis into the news that matters. The same goes for *Q&A* (p75), where the changes we've made will let us answer your brilliant questions in more detail than before.

I'd also like to introduce our new section, *Reality Check* (p32), where we look at the science behind the headlines. In a world where measles is making a comeback, and politicians ignore climate change because it's snowing, it seemed vital to provide a voice of reason to cut through the nonsense. This month, we look at what you can do about air pollution, whether the four-day working week is a good idea, and why screen time isn't necessarily bad.

Towards the back, you'll find *Radar* (p87) where the team has picked out the best TV, radio, books and events. Plus, we'll talk to leading experts to help you get to grips with the latest tech.

We'd love to know what you think, so get in touch at editorialenquiries@sciencefocus.com

Daniel Bennett, Editor

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THIS MONTH I LEARNED ...



COVER: EIKO OJALA

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PETE ETCHELLS

We've all read the headlines: screen time is bad for us. But as psychologist and video games researcher Pete reveals, the story is much more nuanced. → p36



HAYLEY BENNETT

Science writer Hayley explores the incredible engineering that's allowing people to transport rockets, telescopes and Antarctic research bases. → p40



MARCUS CHOWN

Author and broadcaster Marcus meets the researchers who are peering deeper into the Universe than ever before. → p46



ALEKS KROTOSKI

Aleks, presenter of the *Digital Human* on BBC Radio 4, explores how we've become ensnared by the web's taste makers. → p58

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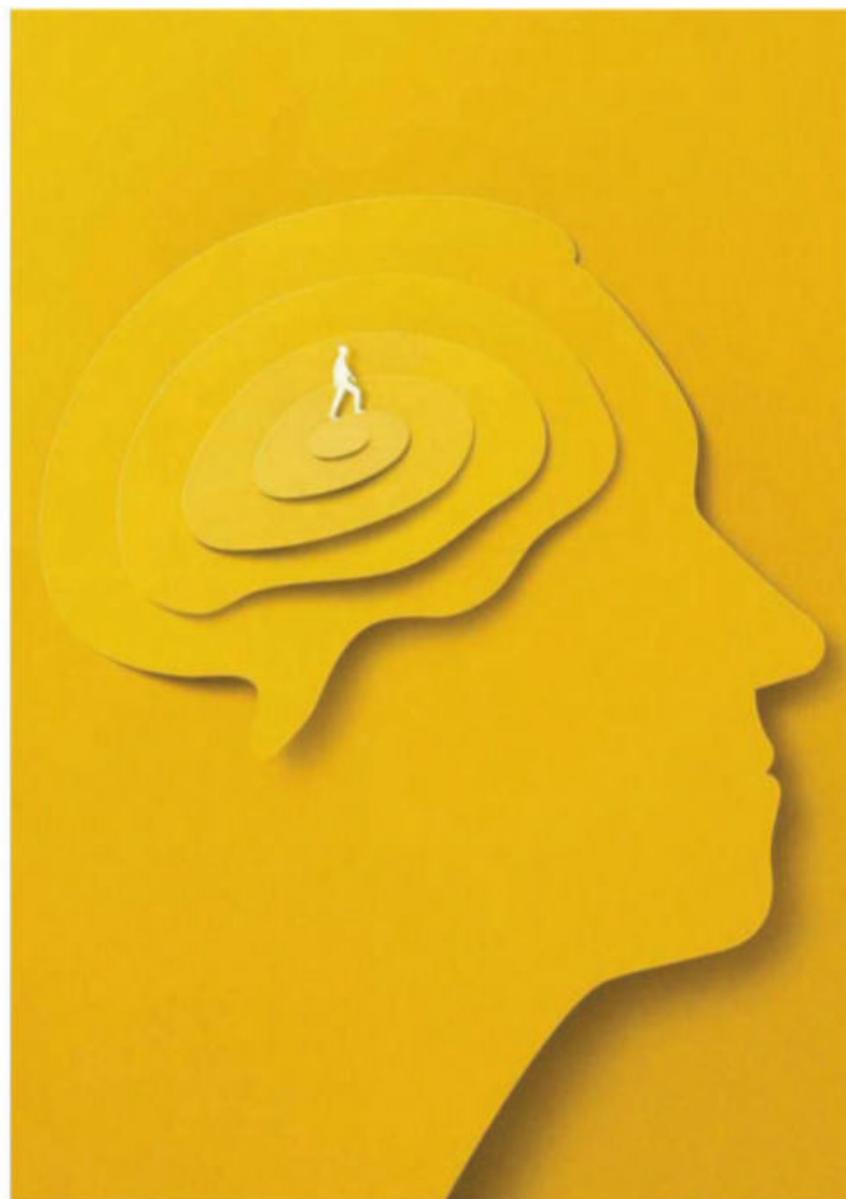
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The way that you think about life can fend off infection, help you live longer and even spare you from the surgeon's knife.

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“I wouldn’t spend 10 minutes shouting at Donald Trump... I’d spend 10 minutes trying to understand him.”

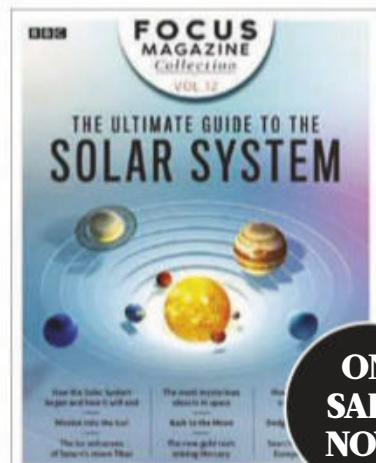
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Don't forget that *BBC Science Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.

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**SPECIAL ISSUE**

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EYE OPENER

Eye on the sky

BEIJING, CHINA

This isn't a close-up of some newly discovered spider, but a bird's-eye view of Beijing Daxing International Airport, currently under construction. The 'eyes' are skylights over the main hub of the terminal. The gates will be located along five spokes radiating from the centre, reducing the distance passengers have to walk: the maximum time to a gate should be eight minutes.

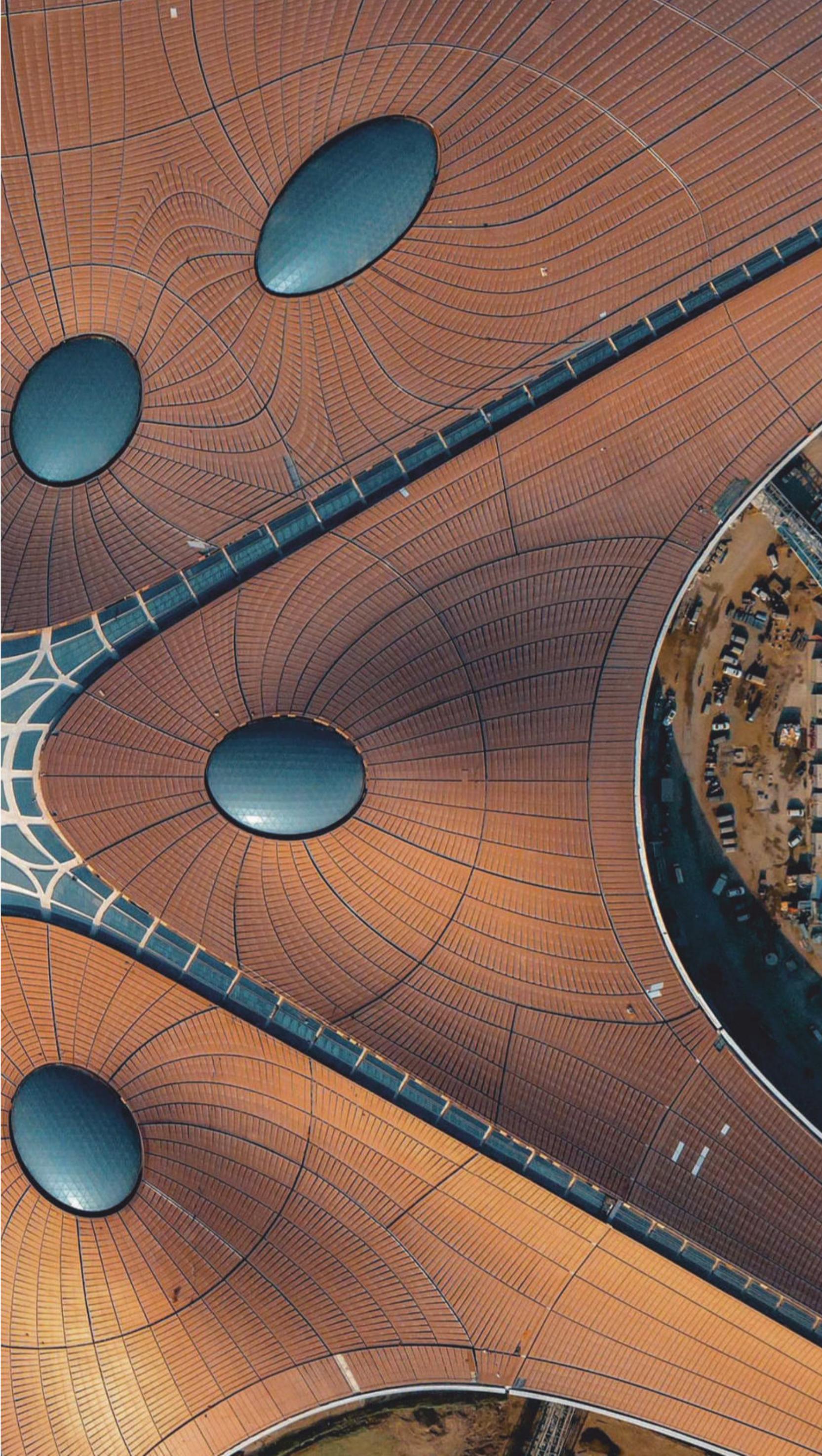
When it opens in September 2019, its four runways will serve 72 million passengers annually. The subsequent opening of a further three runways will bring that number to over 100 million, making it the world's busiest airport. In comparison, London Heathrow served 80 million people in 2018.

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EYE OPENER

Green screen

CES, LAS VEGAS

Nature and technology combine in this installation, which welcomed visitors to the LG Electronics booth at CES earlier this year.

The exhibit featured 260 OLED (organic light-emitting diode) screens. A security guard was on-hand to ensure people didn't clamber over them, with the mirror on the right-hand side of the display making it look like he had a body double.

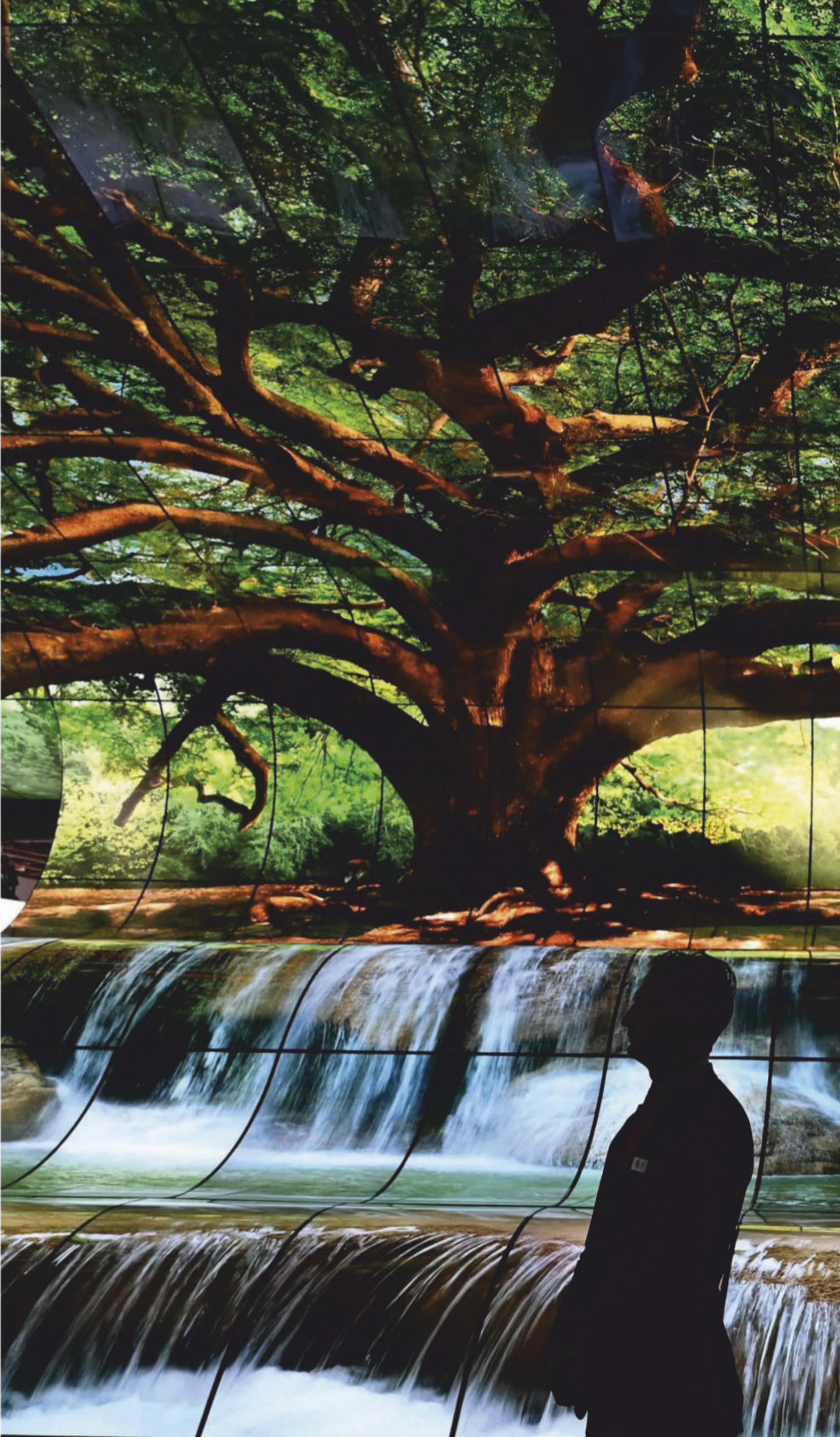
The exhibit was a showcase for LG's flexible OLED technology. Unlike in LCD and LED screens, the pixels in OLED displays are self-illuminating, so they don't need a backlight layer and can be made thinner and more flexible. LG also revealed its new rollable OLED TV, which is due to go on sale later this year for what's expected to be a five-figure sum.

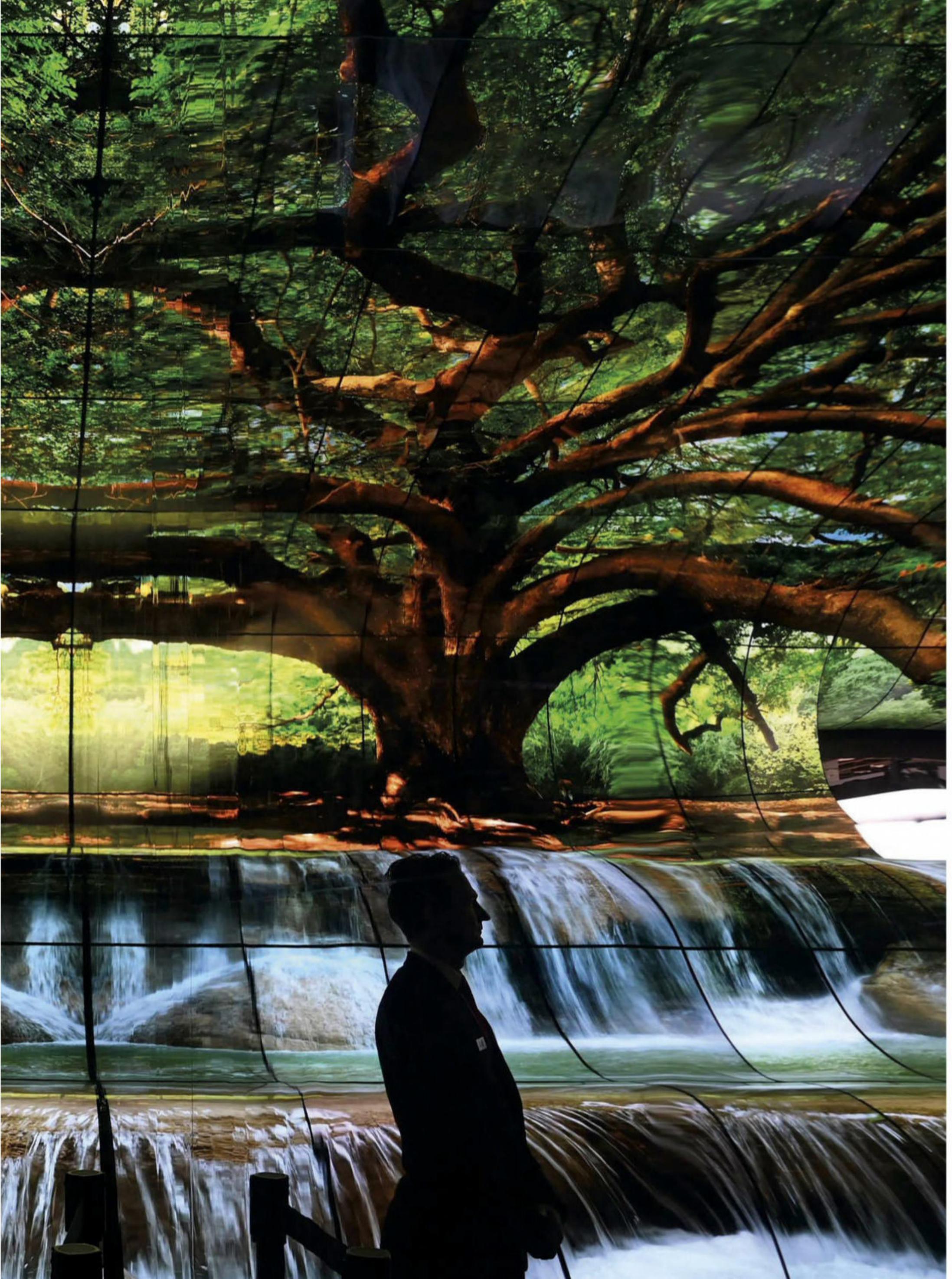
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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND BBC SCIENCE FOCUS

LETTER OF THE MONTH

Moon musings

With regard to the article *A New Race To The Moon Has Begun* in your current edition, (February, p32) the science fiction writer, the late Robert A Heinlein, once wrote: "The laws of nature are not the exclusive property of any group or society; they belong to anyone prepared to make use of them." At the time, he was warning of the danger of the US space program losing ground to the Japanese, but it is at least equally relevant to the Chinese.

As various commentators have pointed out, a few centuries ago, the Chinese Empire sent a number of



expeditions utilising ships significantly larger than their Western equivalents down the eastern coast of Africa.

Had the expeditions continued, Western and Chinese ships could have met, somewhere around the Cape, and changed the history of the world. As it was, the expeditions caused sufficient social unrest among the general population that the bureaucrats running the Chinese government ended the expeditions, even burning the existing log books.

China then turned in on itself, until the Western powers forced themselves to its attention, centuries later. There have already been some comments in the media as to whether China can maintain an authoritarian political system at the same time as a more liberal economic system.

We shall just have to see whether the Chinese have learnt anything from history, and, if so, how much.

The same question could also be asked of the rest of us, of course.

Peter Davey, via email

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins an **STK X2**, the most advanced device to date from the British mobile manufacturer. Running on Android 8.1 Oreo with a super fast processor, the X2 is jam packed with features to take on the big guns. Expect fingerprint technology and an outstanding 16MP camera. stklife.com



**WORTH
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A moment of reflection

I'm currently serving with the RAF in the Falkland Islands, and have never missed a copy since I started a subscription some 17 years ago. I managed to put a few to one side before coming out here, and much to my displeasure I noticed that in issue 326 (September) the question about whether opposing mirrors produce infinite reflections (bit.ly/mirrors_reflection) won *Question Of The Month*, and was awarded a Skullcandy headset...

Well, I sent that very same question in some 12 or 13 years ago, but I wasn't given the honour of *Question Of The Month* nor did I win a prize for ingenuity, originality or even for my handwriting...

If spending six months away from my family in the middle of nowhere defending this small section of the UK territories for the betterment of our nation isn't bad enough, what pleasure I get from reading your magazine was dashed for today when I saw as described...

Oh the humanity! Destined to continue this solitary servitude of an existence with no such rewards...

P.S. Keep up the amazing work, I couldn't do without my monthly science fix.

James Barnard, Falkland Islands

EDITOR: Ah, James, such bad luck! I can only imagine how you're going to feel when you find out you haven't won *Letter Of The Month*... Seriously though, thank you for being such an avid, loyal reader of *BBC Science Focus*.

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ON TWITTER

@StephenCWLL

In an effort to stop getting behind on reading, I've made a cuppa and sat down for two straight hours to get through latest @sciencefocus magazine in record time.

@Dolichon

Nearly through Dry January and I haven't noticed any improvement in health or well being. Does that mean I wasn't drinking enough?

It turns out that a lot of you have heard of James Clerk Maxwell...

@sciencefocus

James Clerk Maxwell: the most important physicist you probably haven't heard of

@Interesting_Ian

Eh?? Never heard of? Would have thought most people would have heard of him. I haven't heard of the majority of celebrities, but have certainly heard of Maxwell!

@wfastronomer

Born in India St in Edinburgh. The Physics and Astronomy Department building in Edinburgh is the James Clerk Maxwell Building, and there is a James Clerk Maxwell Telescope in Hawai'i, which having been sold by the UK is now run by the East Asian Observatory.



"I WOULDN'T SPEND 10 MINUTES SHOUTING AT DONALD TRUMP... I'D SPEND 10 MINUTES TRYING TO UNDERSTAND HIM"

CHRIS PACKHAM, p52

It's a state of mind

I was fascinated to read about the condition known as aphantasia (February, p62), where people cannot picture things in their mind. I always knew that I had more of a vivid imagination than most other people, but didn't realise that there were people who couldn't form mental pictures at all.

Reading the article made me realise that I fitted at the opposite end of the spectrum and had hyperphantasia. My mental imagery is so powerful that I often disconnect from the real world and run on autopilot.

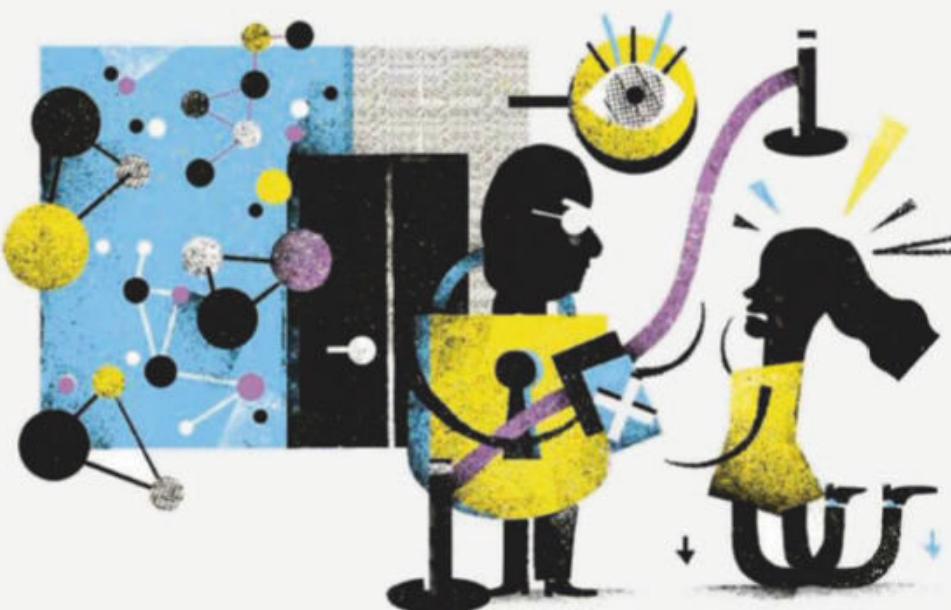
While my ability to visualise helps me as a photographer, it can also be unnerving at times. When I am having a conversation while driving, for instance, I visualise the topic of the conversation so powerfully that I become unaware of the road and drive on autopilot. In childhood it was classed as daydreaming. As an adult, when I flip between reality and my vivid mind's eye, it becomes more awkward. As a creative person, I would still rather be with it, though, than without it.

David Stocks, Walsall

Plastic fantastic

I was overjoyed to read about a plastic-eating enzyme that has been engineered that could digest waste plastics (June, p20).

However, I am curious whether Prof John McGeehan of Portsmouth University would ever consider reintroducing the engineered enzyme back into the bacteria and allowing the



bacteria to proliferate naturally. This is something enzymes themselves are unable to do.

Russell Tan, via email

EDITOR: That is the next logical step, but there are still tight

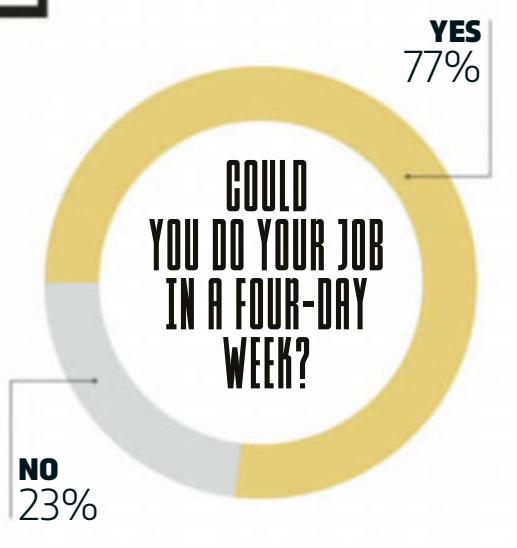
regulations (rightly so) about the kinds of engineered organisms that can be released into the wild. It's the very same reason we don't see glow-in-the-dark trees instead of street lights... yet.

"WESTERN AND CHINESE SHIPS COULD HAVE MET, AND CHANGED THE HISTORY OF THE WORLD"

READER POLL

Workplaces around the world are trying to increase productivity by shortening working hours without changing pay. Could you do your job with only four working days a week?

Turn to p34 to find out what the research says



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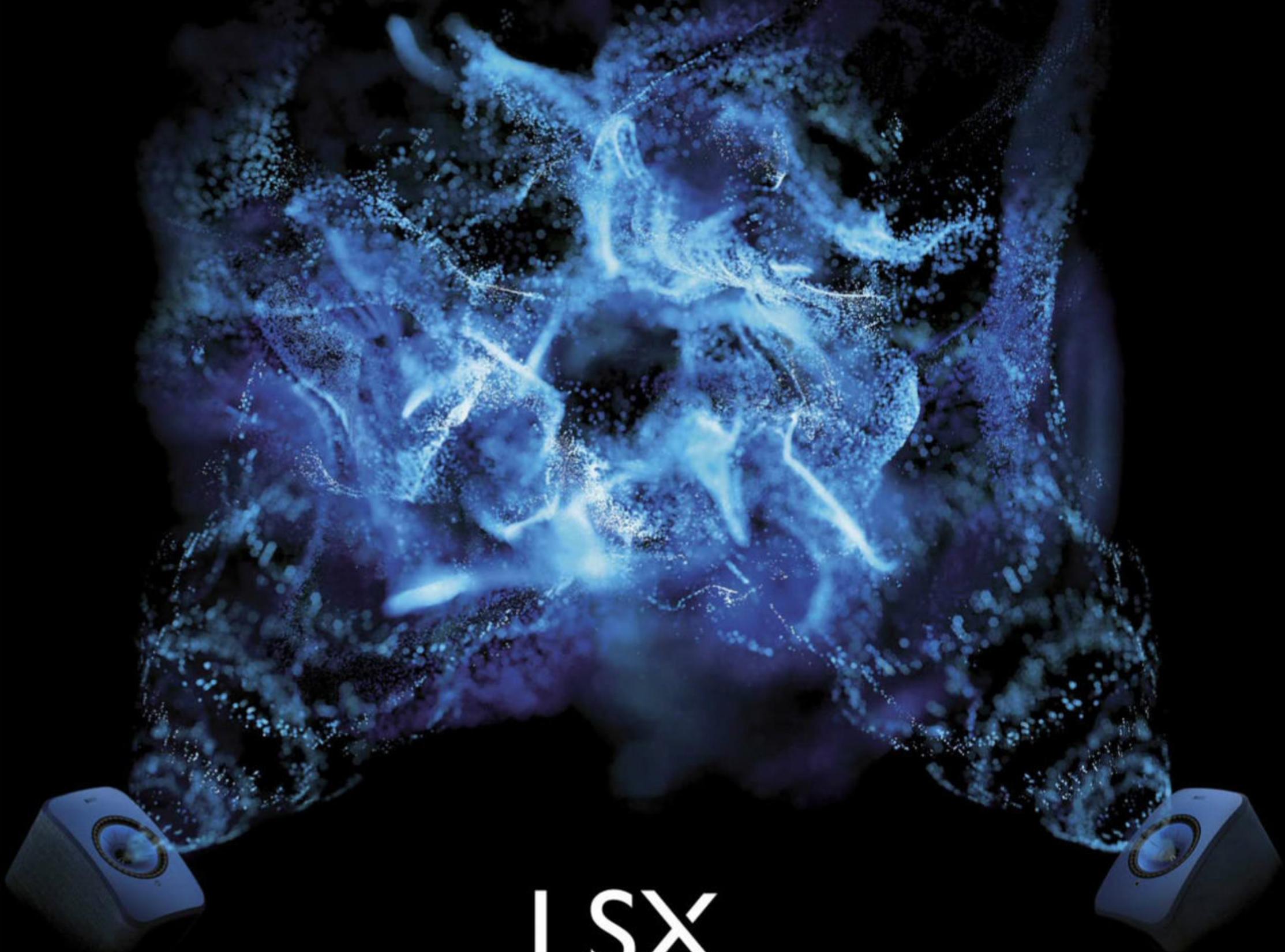
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GM MACAQUES

Researchers have cloned mentally ill macaques p30

SUPER POOPERS

Faecal transplants could help cure disease p20

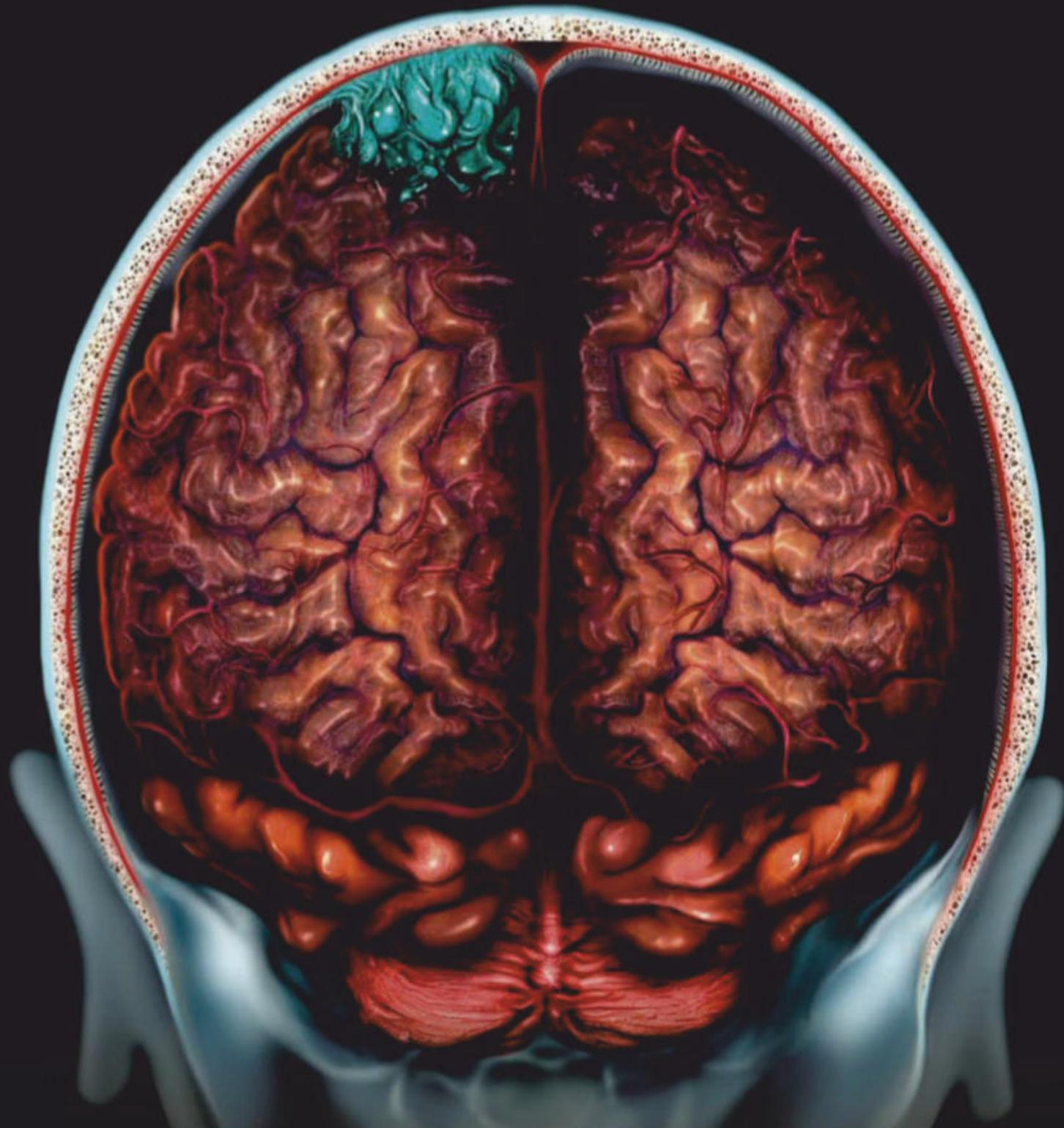
EGGCELLENT

Chickens that lay cancer killing eggs p26

TREKKIE TECH

A replicator that uses light to create objects p17

DISCOVERIES



Implant lures tumours out of the brain

Tumour-killing 'monorail' project given fast track to human trials by the US Food and Drug Administration

When it comes to treating brain tumours, surgeons face a major problem: how do you remove cancerous cells without damaging the healthy tissue that surrounds them? Now, a team at Georgia Institute of Technology think they have the answer – trick the tumour cells into moving in a certain direction by luring them, Pied Piper-style, out of the brain. For the past five years they've been developing a device they call a "tumour monorail", and after successful trials in rats they have just been awarded 'breakthrough status' by the US Food and Drug Administration (FDA).

News in brief

PATIENT, LOVE THYSELF

Self-compassion can calm the heart and reduce feelings of distress, according to a recent study. Volunteers were played recordings that either told them to be kind to themselves, or were more critical. Those who heard the first set had reduced heart rates. The others' hearts beat faster and they started to sweat. According to the University of Exeter researchers, being kind to yourself relaxes the body, which can boost the immune system and help with healing.



The device is essentially a long, thin tube made of fine, flexible fibres that is fed through a narrow opening connecting the brain's left and right hemispheres. It takes advantage of the fact that tumour cells spread through the brain along fibres of white matter – bundles of brain tissue that connect areas of grey matter together and carry messages between neurons. By providing them with an alternative pathway, it is able to lure cancerous cells out of the brain, preventing their spread into areas of healthy tissue.

"This was the first demonstration that you can engineer migration inside the body and move a tumour from point A to point B by design," said Prof Ravi Bellamkonda, who began the research while at Georgia Tech. "It was also the first demonstration of bringing the tumour to your drug rather than your drug going into the brain and killing valuable cells."

The tumour cells are guided into a tiny reservoir that sits on top of the skull, beneath the scalp. Siphoning some of the cells out of the reservoir after they are collected could prevent the spread of the tumour or even shrink it significantly. Preliminary trials on rats showed that

the device is capable of reducing the size of tumours by more than 90 per cent. Alternatively, the monorail could be used alongside other treatments to boost their overall effectiveness, since smaller tumours are more easily treated.

While the monorail has been specifically designed to mimic white matter to treat brain tumours, the team says the same concept can be used to treat other different types of tumour. It could be particularly useful for tumours in parts of the body which are hard to access, by moving them to a more accessible location where they can be removed surgically.

"Many tumours, from breast cancer, to prostate, to pancreatic tumours, actually respond to this structural cue. It's not specific to brain tumours, meaning that if you give them the fibre-like structures, these tumour cells love to grow along them," said Bellamkonda.

So far, the device has only been tested on rats but its designation as a 'breakthrough device' should help the team gain approval for human trials by the end of the year.

For the latest science news, visit sciencefocus.com

HOW IT WORKS

STEP 1. The flexible nanofibres are inserted into the space between the left and right hemispheres of the brain.

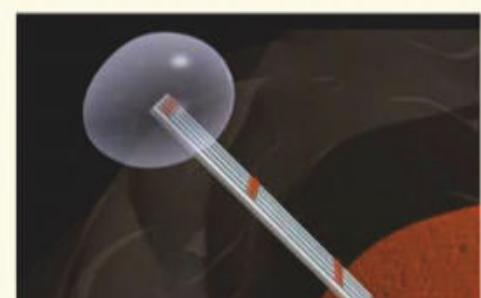


Studying an MRI scan prior to removing a brain tumour

STEP 2. The fibres mimic the brain's white matter, luring the cancer cells along them.

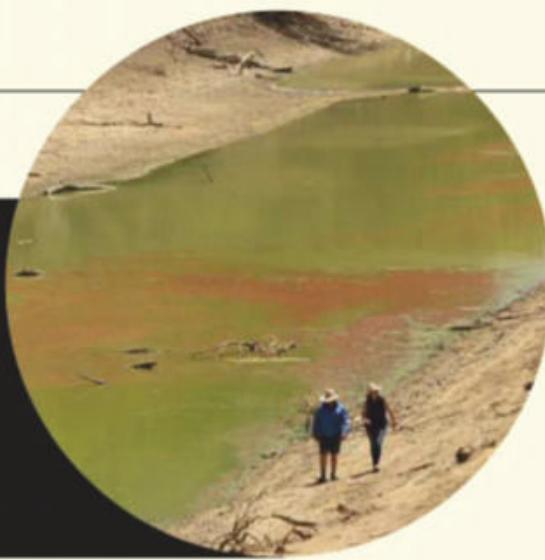


STEP 3. The cancerous cells move to a reservoir located under the scalp, where they can be removed or destroyed.



BURNING UP

The global average temperature from now until 2023 is forecast to be near or over 1°C above pre-industrial levels. If the prediction is correct, then the decade from 2014 to 2023 will be the hottest decade since records began more than 150 years ago. The study placed 2018 as the fourth warmest year on record.



They did what?

Scientists gave diet pills to mosquitoes

WHAT DID THEY DO?

Researchers at Rockefeller University, led by Leslie Vosshall, gave diet drugs to female *Aedes aegypti* mosquitoes.

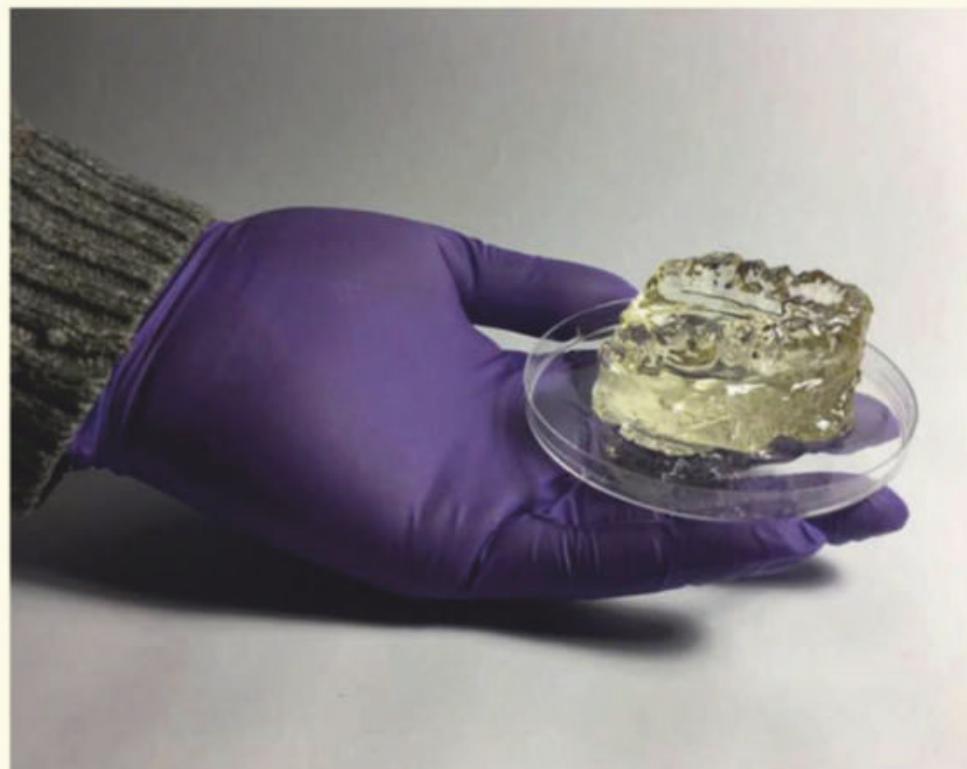
WHY DID THEY DO THAT?

Unlike male *A. aegypti* mosquitoes, the females feed on human blood. In the process of feeding, they spread pathogenic viruses like yellow fever, dengue, Zika and chikungunya. As the flies are becoming more resistant to insecticides, the researchers think that artificially suppressing their appetites might provide an alternative way to reduce the spread of disease.

WHAT DID THEY FIND?

The drug inhibited biting and feeding behaviours when the mosquitoes were exposed to the scent of a human or a source of warm blood. "When they're hungry, these mosquitoes are supermotivated. They fly toward the scent of a human the same way that we might approach a chocolate cake," said Vosshall. "But after they were given the drug they lost interest."

A dental model created from gooey resin, using the new 3D-printing technique



MATERIALS

It's 3D printing, Jim, but not as we know it

'Star Trek replicator' uses light to create 3D objects in minutes

Scientists at the University of California, Berkeley have invented a 3D printer that uses light to transform gooey liquids into solid objects.

Nicknamed ‘the replicator’ after the *Star Trek* machine that makes things on demand, the device can create objects that are smoother, bendier and more complex than those made with standard 3D printers.

First, researchers make a 3D computer model of the object, which an algorithm then converts into a moving sequence of 2D images – essentially a movie – that shows the object from every angle. This movie is then beamed onto a rotating vat of gloopy, light-sensitive resin which becomes solid when exposed to light. Once the process is complete, the remaining liquid is poured away to reveal the fully-formed sculpture.

So far, the printer has made a customised jawbone, toy planes and bridges, and a tiny version of Rodin's *The Thinker*. It can print objects up to 10cm in diameter, but the researchers are thinking bigger.

Conventional 3D printers build objects up one layer at a time. This typically gives a jagged ‘stair-step’ effect along the edges, and makes it difficult to create bendy objects. The new printer gets around that problem by creating the entire shape in one go. It’s also able to cope with tricky features such as overhangs and disconnected parts.

Dental implants and architectural models are just a few potential uses for this technology. "This is the first case where we don't need to build up custom 3D parts layer by layer," said co-author Brett Kelly. "It makes 3D printing truly three-dimensional."





FISH PASSES MIRROR TEST

Cleaner wrasse are able to recognise themselves in a mirror. A team at Osaka City University observed the fish looking at their reflections in a mirror and trying to remove marks that had been put on their bodies. Only a few other animals have passed the test, which is designed to establish self-awareness.

Trending

Your guide to the hottest topics in the world right now and who's saying what

#MassExtinction

A global review of the world's insects carried out by Australian researchers has found that 40 per cent of all species are threatened with extinction in decades. Nearly all insects could die out within a century, they say.

Chris Packham @ChrisGPackham

Greed for money is driving this apocalypse. The agrochemical giants' power over the farming lobbyists who have brainwashed the farmers into thinking that we need poisons for produce. It's a lie and earth is dying @DaveGoulson @GeorgeMonbiot @ExtinctionR

George Monbiot @GeorgeMonbiot

The greatest cause of this collapse is the way we produce our food. The ecological implosion caused by current farming and fishing methods is happening even faster than climate breakdown



#Allblacks

Former Irish international rugby player Emmet Byrne claimed that the All Blacks are genetically superior to the Irish when it comes to rugby skills and that it would take 200,000 years of evolution for the Irish to catch up.

Aylwyn Scally @aylwyn_scally

No, genetics has little or nothing to do with why the @AllBlacks are good at rugby. And that's not how evolution works either

Dr Adam Rutherford @AdamRutherford

This is a terrible and specious argument, and though well-intentioned, is no different from any racialised myth of athletic success

Richard Sever @cshperspectives

You mean it's not some rogue antipodean sports gene drive that spread rapidly through both the native and white populations of Australia and New Zealand via ?;-)



#WomenInScience

11 February was named International Day of Women and Girls in Science by UNESCO. The aim is to promote full and equal access to and participation in science for women and girls.

Rachel Riley @RachelRileyRR

Thanks to physics, I've been able to zipwire through fire, ride a bike on a tightrope 5 storeys up AND balance a cardboard parrot on my head (3 separate stunts) without burning or dying yet! Never let me down so far, big fan @PhysicsNews @Stemettes #WomenInScience #STEM

Sophie Farooque @LondonAllergy

At school they told me that I was too stupid to study medicine (I was rubbish at maths). Now I lead one of the UK's oldest allergy clinics. A BSc, MRCP, PhD later, my greatest academic achievement remains my grade C in A-level maths. Don't let anyone put you down! #WomenInScience



#Opportunity

NASA officially declared its Opportunity Rover mission over on 19 February, after 14 years of exploring the surface of Mars. The rover entered hibernation in June 2018 after being affected by a planet-wide dust storm. It hadn't answered communications attempts since August 2018.

Buzz Aldrin @TheRealBuzz

Come on buddy... don't give up on us now! #MarsRover #Opportunity

Scott Kelly @StationCDRKelly

Designed to last 90 days but persisted 14 years. You were more than #Opportunity; you were a testament of endurance and an example of pushing boundaries. #ThanksOppy

KEEP IN TOUCH



@SCIENCEFOCUS



BIOLOGY

Flying squirrels glow pink in UV light

An accidental discovery sparks a new investigation



In what surely must be a career highlight, Dr Jon Martin of Northland College, Wisconsin, stumbled upon the bizarre effect when out looking for fluorescent lichens, mosses and plants using a UV torch in his back garden. By chance, a flying squirrel was out scavenging food from his bird feeder. When he shone his torch on it, the squirrel's fur fluoresced a vibrant Cheshire Cat pink.

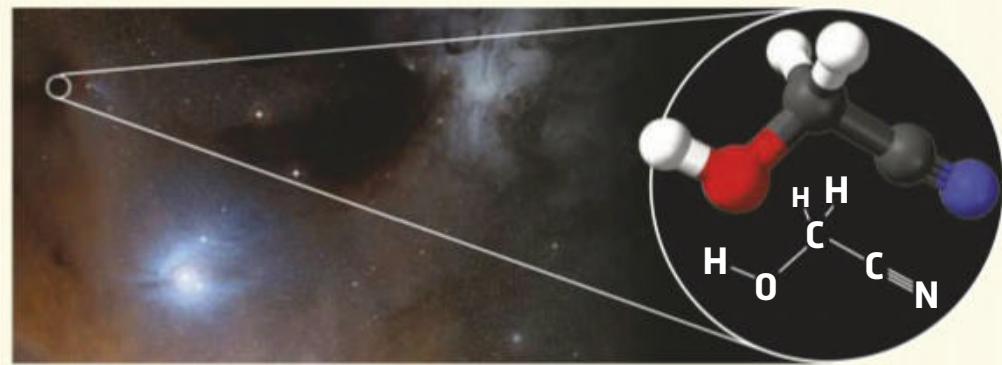
Puzzled by what he had seen, Martin assembled a team to investigate the effect in stuffed flying squirrels stored at the Minnesota Science Museum and the Field Museum of Natural History. All of the 100 animals they found glowed pink under UV. They found the same effect in five live species of flying

squirrel but it was not seen in non-flying red and grey squirrels.

The exact purpose of the squirrels' glowing fur is unknown, but camouflage or communication are likely to be involved. "They could be communicating with members of their own species by showing off their fluorescence to each other, or it might be a sort of mating display," says research team leader Allison Kohler. "The other hypothesis is that they could be using this fluorescence as an anti-predator trait to communicate with other species, avoiding predation by other species by blending in or dealing with their potentially ultraviolet-saturated environments."

WE ARE ALL MADE OF STARDUST

Glycolonitrile, an organic chemical similar to those that make up the components of DNA, has been found in the gas and dust around a newly forming star. The star, IRAS 16293-2422 B, is in the early stages of formation but will develop into something similar to the Sun. This suggests that planets around stars like our Sun may have formed with some of the components for life ready to take hold.

**BIOLOGY**

Are you a super pooper?

A trans-poo-sion could potentially help treat Alzheimer's, cancer and diabetes

Another person's poo may not seem like the best way to cure what ails you, but faecal transplants have been used to treat *Clostridium difficile* – an unpleasant infection where a particular species of bacteria overruns the bowel, causing recurrent diarrhoea – with a 90 per cent success rate. In a faecal transplant, poo from a healthy donor is transplanted into a patient, either via a tablet or an enema, in order to fill their gut with friendly bacteria and help fight illness. Trials for treating other conditions, such as inflammatory bowel disease and type 2 diabetes, have not been as successful as those for *C. difficile*. But a recent study by the University of Auckland found that some 'super poopers' have faeces that contain bacteria which offer higher cure rates. "The pattern of success in these trials demonstrates the existence of 'super donors', whose stool is particularly likely to influence the host gut and to lead to clinical improvement," said senior author Dr Justin O'Sullivan.

The scientists hope that by studying these donors' stools, they can improve the success of faecal transplants and use them to treat conditions like Alzheimer's, multiple sclerosis, heart disease, cancers and asthma, which seem to be associated with a microbiome that's out of whack.

"Super donors provide us with a unique opportunity to learn more about the microbiome component of chronic diseases, like irritable bowel syndrome or obesity," said Brooke Wilson, co-researcher and PhD student at the University of Auckland.

The super poopers appear to have a greater diversity of gut microbes and high levels of chemical-producing bacteria called 'keystone species', which are



absent in the sick patients. For example, one keystone species produces butyrate, which is associated with improvements in inflammatory bowel disease and diabetes. Butyrate regulates the immune system and is linked with how the body generates energy from food.

But by digging deeper, the researchers have found it isn't just the bacteria that are helpful, but also the other substances inside the poo, such as DNA, viruses and other debris. Plus, transplant success rates can be improved if a recipient modifies their diet to feed their new microbes.

Rod-shaped *Clostridium difficile* bacteria, which can cause illness if they overrun the bowel

453,000

The number of *Clostridium difficile* infections in the US every year.



There are 20,000 genes in the human genome, and up to 20 million genes in the microbiome.

A small study found that the average BMI of patients went down from 28.9 to 27.4 after a trans-poo-sion.



In numbers

3.8
years

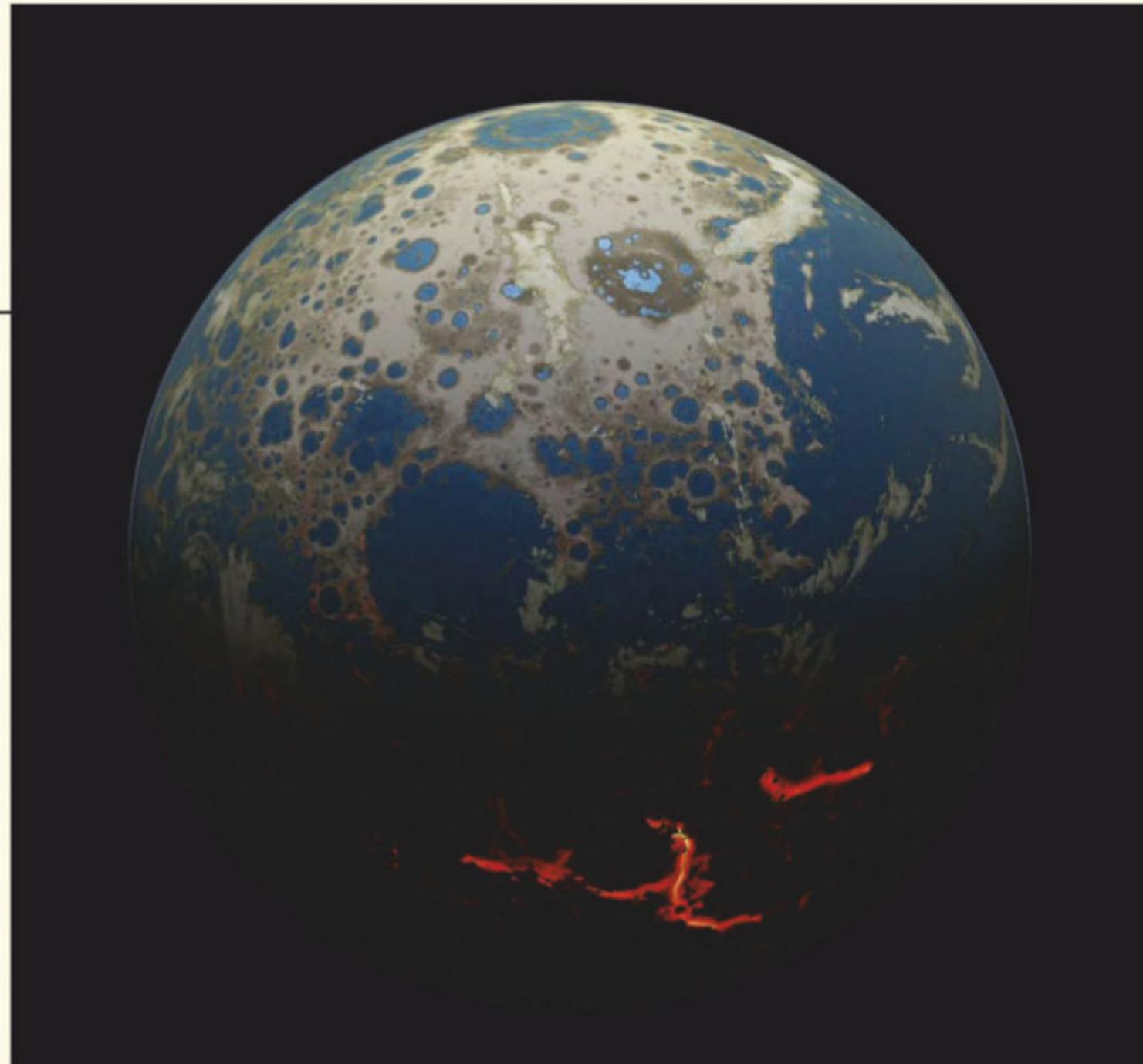
The metabolic age that a woman's brain appears to be younger than a man's of the same chronological age, according to a study at Washington University. It could explain why women tend to stay mentally sharp longer than men.

99.99%

The percentage of bacteria killed in 10 litres of water by a new purification material. When exposed to light, the substance releases oxygen-based chemicals that destroy microbes.

**10 hours,
33 minutes
and 38
seconds**

The length of a day on Saturn, as determined using data recorded by NASA's Cassini probe.



SPACE

Ancient Earth rock discovered on Moon

A rock that may be one of the oldest known to have originated on Earth has been found in a hoard of samples brought back from the Moon by the Apollo 14 astronauts in 1971.

It is thought that the rock formed about 20km beneath the Earth's crust, before being launched into space after a large asteroid or comet slammed into the planet's surface about four billion years ago. It then travelled through the Earth's primitive atmosphere before crash landing on the Moon, which was three times closer to the Earth than it is today, and got mixed with material on the lunar surface as it was bombarded with other hurtling space rocks.

The 2g fragment contains quartz, feldspar,

and zircon – all minerals rarely found on the Moon, but common on Earth – and was identified by an international team of scientists based at the Center for Lunar Science and Exploration (CLSE).

"It is an extraordinary find that helps paint a better picture of early Earth and the bombardment that modified our planet during the dawn of life," said principal investigator Dr David Kring.

The researchers note that their discovery is likely to be controversial in some corners of the geology community as it is the first finding of its kind, but they are hopeful that the results will be confirmed when further similar samples are found in future studies.

Earth looked much different when the ancient rock fragment formed



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Flares® PRO

"These are the best earphones ever! I mix on these. The detail, the clarity and low end are 'pinch me am I dreaming?' great."

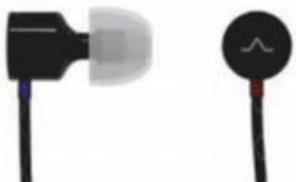
Tony Visconti: Grammy award-winning producer
(David Bowie, T-Rex, Iggy Pop)



Flares® JET

"They're easily the best in-ear earphones I've ever used. Lovely bottom end, beautiful depth and clarity to the overall sound. It's quite unbelievable."

Pete Paphides: DJ and Music Journalist: Melody Maker, The Guardian, Time Out, Q Magazine



Flares® JET 1
Polymer



Flares® JET 2
Aluminium



Flares® JET 3
Titanium

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Traditional earplugs are made of soft plastics or foams that merely muffle sounds. Isolate® and Sleeep® earplugs use titanium and aluminium suspended in soft memory foam to block irritating noises.



Isolate®



Sleeep®

Primer

5G: The game-changer

THE BLISTERING SPEED AND VERSATILITY OF THE COMING 5G NETWORK HERALD A QUANTUM LEAP FOR MOBILE TECHNOLOGY. HERE ARE THE FAST FACTS...

WHAT IS 5G?

5G is the fifth generation of mobile networks, following on from 2G, 3G and 4G. But while the move from 3G to 4G was all about speeds, 5G is about so much more. Sure, 5G is extremely quick, but it's also stable and reliable, with characteristics that will allow it to form the underlying communication networks for connected vehicles, virtual reality worlds and robotics systems. The new network's greater capacity will allow these bandwidth-hungry applications to run simultaneously, without having the knock-on effect of slowing down the network for other users.

HOW DOES IT WORK?

Like its predecessors, 5G is transmitted via radio waves. It will use some frequencies that are in the 4G range, as well as a higher frequency, called millimetre wave technology. The latter enables the speed and capacity that 5G needs, but this frequency transmits at a shorter wavelength and can't transmit as effectively through walls. It can even be sensitive to environmental factors such as rain. To get around this, engineers are looking to install additional hardware to boost transmissions.

WHEN IS IT COMING?

Trials of 5G technology are currently taking place but it is predicted that a fully standardised version will start to

reach UK consumers in 2020. When it arrives, it will most likely focus on urban areas first, with widespread use of the technology taking a bit longer: the UK government says it will be rolling out 5G nationwide by 2027, so we won't be seeing it in autonomous cars and other more advanced applications for another 5 to 10 years.

HOW FAST IS IT?

Much faster: 5G will bring an expected tenfold surge in speeds compared with today's 4G networks. It's predicted that 5G will be as fast as 1 gigabit per second



“Thanks to 5G, self-driving cars will network with other vehicles almost instantly, reacting to events on the road en masse and in real time”

(Gb/s), with some claiming it could reach 10Gb/s. The benefits of this speed are huge: you could download an HD movie in seconds, allowing you to watch high-quality content even while on the move. In addition to faster speeds, 5G's ability to provide low latency means even browsing the internet on your device will be much quicker. The greatest difference will arguably be seen in bandwidth-heavy activities such as online gaming, which will see lag times drastically cut.

Low latency will also be key for the widespread introduction of self-driving cars: thanks to the high speeds of 5G, autonomous vehicles will be able to network with others almost instantly, reacting to events on the road en masse and in real time, boosting safety.

WILL I NEED A NEW PHONE?

Yes, but it won't be hard to find one. 5G smartphones, such as the Samsung Galaxy S10, OnePlus 7 and Huawei P30, will be on the high street this year. Also, rumour has it that Apple is trying to source a 5G modem in time for its next iPhone launch, expected in September this year.

But there's no need to rush to the shops. 5G won't be widely available in 2020, and initially on a limited geographical basis, so it makes sense to bide your time and wait for your upgrade window to roll around.

WILL IT WORK IN RURAL AREAS?

Currently, just 41 per cent of rural premises have 4G coverage, according to regulator Ofcom's 2018 annual report. This compares with 81 per cent in urban areas. There is hope that this will improve with 5G. Vodafone has already selected a number of rural locations to be first to receive 5G coverage, and a government-backed testbed called 5G RuralFirst is working on setting up the technology outside of urban areas.

WILL IT MEAN THE END OF FIXED LANDLINES?

5G won't replace fixed-line broadband, but it could be an effective substitute in some areas. 4G networks are already used to provide 'fixed wireless access' – a permanent wireless broadband connection set up between two fixed locations. Experts think 5G could do the same, but with greater connection speeds and efficiency. So much so that the technology is being considered as a means to provide reliable and fast 'last mile' connectivity to homes and businesses, making that physical wire to your home obsolete. It's fairly simple to set up, so some experts are saying this could be among the first applications of 5G as it starts to roll out this year.

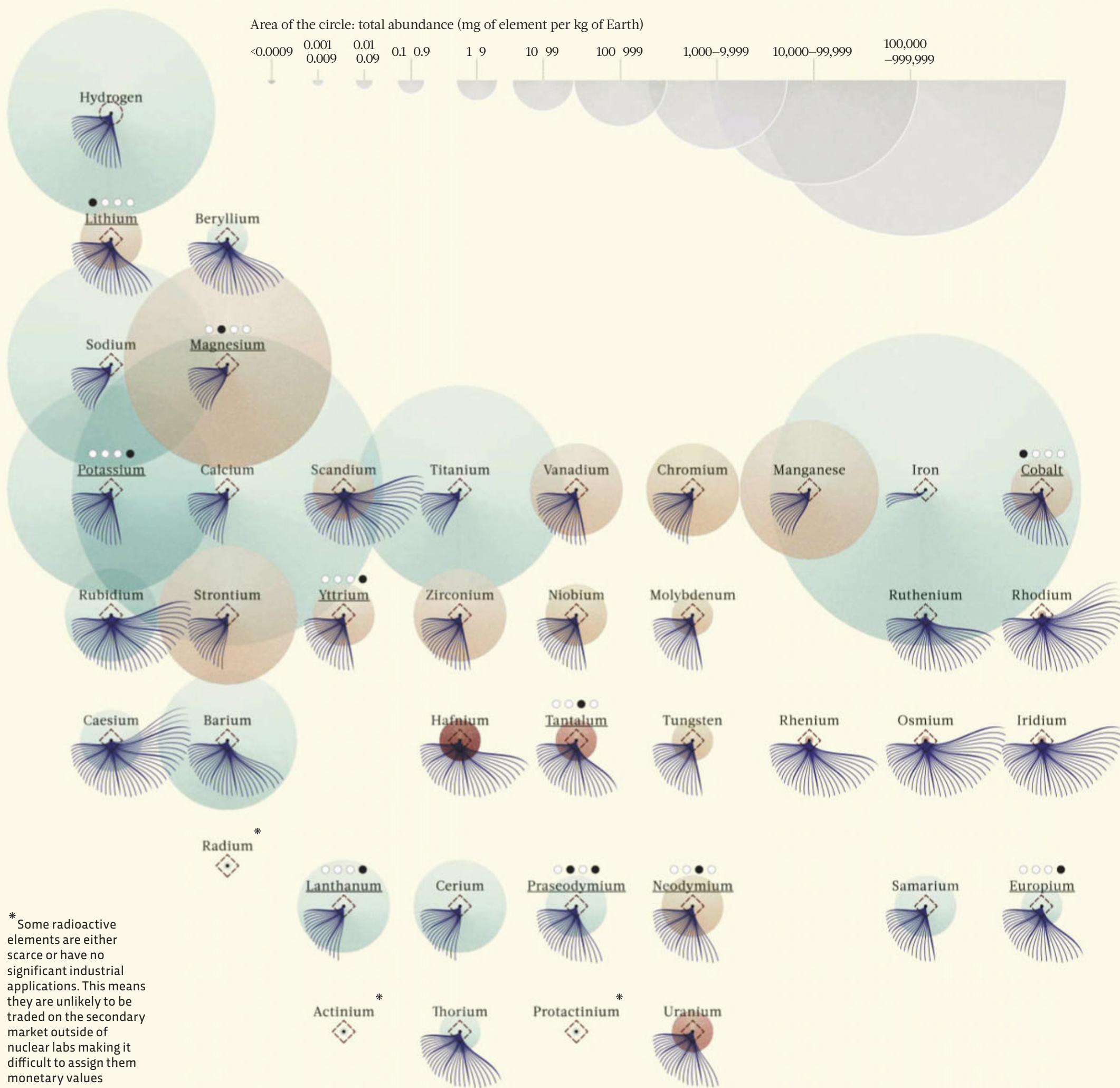
KATE O'FLAHERTY

Kate is a freelance technology journalist.

Data crunch

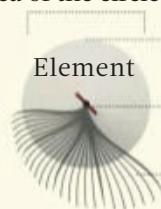
ELEMENTS IN DANGER

This year marks 150 years since Russian chemist Dmitri Mendeleev published the first recognisable version of the periodic table – a visual representation of how chemical elements relate to one another. Since then, the substances depicted have been used to make everything from rocket fuel to raincoats, but our overreliance on some – especially those used in smartphones – is starting to put a strain on resources.



LEGEND

Area of the circle: total abundance on Earth (mg/kg)

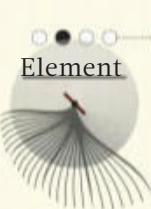


Colour of the circle: scarcity

Symbol: state at room temperature

Number of lines: price per kg

Underlined elements: the ones used in phones

Black circle: part of the smartphone the element is used in:
battery electronics
casing screen

Colour of the circle: scarcity

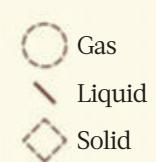
Plentiful supply

Rising threat from increased use

Limited availability, future risk to supply

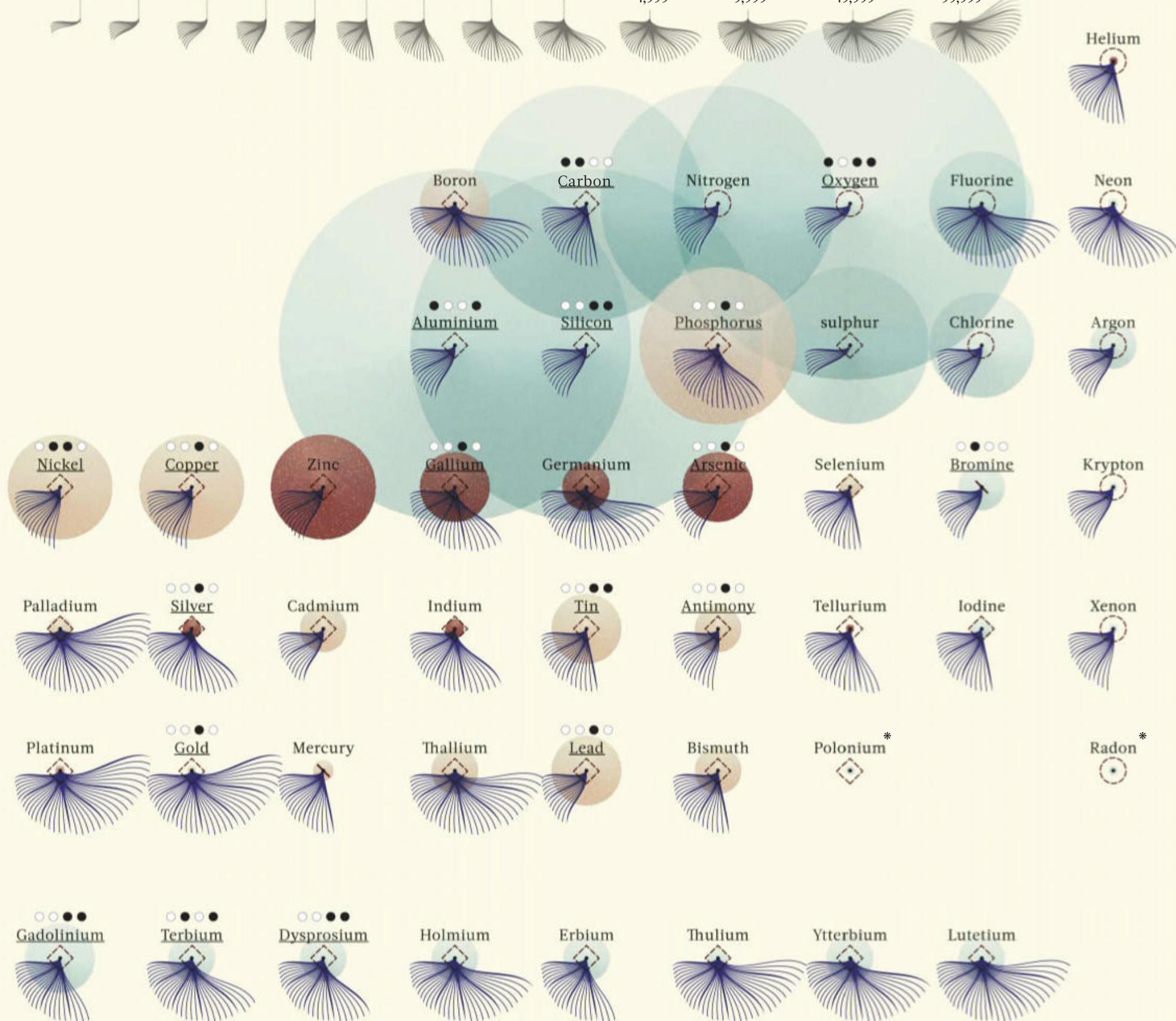
Serious threat in the next 100 years

Symbol: state at room temperature



Number of lines: price per kg (\$ /kg)

<0.1 0.1–0.49 0.5–0.9 1–4.9 5–9 10–49 50–99 100–499 500–999 1,000–4,999 5,000–9,999 10,000–49,999 50,000–99,999



**LAZY LANGUAGE LEARNERS**

Scientists at the University of Bern played a made-up language and its interpretations (such as 'tofer' = 'key' and 'guga' = 'elephant') to napping test subjects. Upon waking, they couldn't recall the words' meanings, but were able to categorise them (they knew a tofer was something small, and a guga was something large).

TRYPANOPHOBES

Got a fear of needles? Help may be on the way. A team at MIT has developed a pill the size of a pea that can inject a shot of drugs directly into the stomach lining after being swallowed.

Good month**Bad month****CHIP LOVERS**

British chips were 2.5cm shorter last year, thanks to extreme heatwaves starving UK potato plants of water over the summer and preventing them from growing to their usual size, according to a study at the University of Leeds.

CITY DRIVERS

The limited availability of spaces and high parking fees in cities could make it cheaper for autonomous vehicles to cruise around slowly rather than finding somewhere to park. According to transportation planner Adam Millard-Bell at the University of California, Santa Cruz, this means they'll be adding to urban gridlock rather than reducing it.



GETTY IMAGES X4; ILLUSTRATIONS: ELENA XAUSA

ZEBRA STRIPES CONFUSE FLIES

Though commonly thought to provide camouflage from predators, a zebra's distinctive stripes may have another use – deterring horse flies. A team at the University of California has found that horse flies landed on zebras less than one-quarter as often as they landed on horses kept in the same enclosure. The effect was also seen in horses dressed in stripy coats.

**BIOLOGY**

An egg a day keeps the doctor away

Genetically modified chickens lay eggs rich with cancer-killing proteins

This is no yolk: scientists at the University of Edinburgh's Roslin Institute have produced genetically modified hens whose eggs carry proteins that the human immune system uses to fight disease – the same proteins used to make types of drugs, including cancer medication. The research could pave the way for a cheaper means of mass-producing medicine. The technique does not harm the chickens.

The researchers concentrated their efforts on two proteins: IFNalpha2a, which has

powerful antiviral and anti-cancer effects; and macrophage-CSF, which is involved in the repair of damaged tissues. In both cases, once the eggs had been laid, the scientists could extract the proteins.

"We are not yet producing medicines for people, but this study shows that chickens are commercially viable for producing proteins suitable for drug-discovery studies and other applications in biotechnology," said Prof Helen Sang, a developmental biologist at the Roslin Institute.

Protein-based drugs, such as Avastin and Herceptin, are widely used for treating cancer and other diseases. Some of these drugs can only be produced using techniques in which cells are removed from an animal and grown in a controlled artificial environment. The researchers say their new approach is cheaper, more efficient and produces better yields.

Three eggs produce sufficient proteins for a dose of medicine, and each hen can lay up to 300 eggs a year





NEUROSCIENCE

Brain waves translated into speech

Just call it thinking out loud. Researchers at Columbia University have translated someone's brain activity and turned it into clear, understandable speech.

When we speak, listen, or even just imagine speaking or listening, distinct patterns of activity are produced by our brains. To translate these patterns into speech, the researchers used a vocoder – the same technology that's used by Amazon Echo and Apple's Siri – to synthesise speech and respond to your voice commands.

To teach the vocoder to interpret brain activity, the team worked with a group of epilepsy patients who were already undergoing brain surgery. The patients' brain activity was recorded as they were listening to someone recite the numbers zero through to nine. Those signals were then run through the vocoder, which turned them into speech. Artificial intelligence was then used to analyse

and clean up the sound produced by the vocoder. They were left with a robotic voice that recited the numbers the patients were hearing. About three-quarters of the time the numbers were correct and understandable. The goal is to train the vocoder to produce speech based on brain signals emitted when a person imagines speaking. In future, they might be able to produce an implant that translates the wearer's thoughts into words. This could be life-changing for people with conditions like ALS who have lost their ability to speak.

"If the wearer thinks 'I need a glass of water,' our system could take the brain signals generated by that thought, and turn them into synthesised, verbal speech," said lead author Dr Nima Mesgarani. "This would be a game changer. It would give anyone who has lost their ability to speak, whether through injury or disease, the renewed chance to connect to the world around them."

ABOVE:
Volunteers
had
electrodes
attached to
their brains
while
undergoing
surgery, to
track brain
activity
as they
listened to
someone
talking

RIGHT:
Nerve cells
(visualised
here)
can die,
impairing
speech.
This new
technology
could help

AMYOTROPHIC LATERAL SCLEROSIS (ALS)

This condition is also known as motor neurone disease (MND). It's a progressive disease in which the nerve cells responsible for voluntary movements, like chewing, walking and talking, deteriorate and die.





Ciaran Beggan geophysicist

Horizons

Magnetic pole position is racing westward. Why?

Magnetic north is moving so fast it's defying predictions and ruining maps. CIARAN BEGGAN of the British Geological Survey brings us up to speed

WHY DOES THE MAGNETIC NORTH POLE MOVE, AND WHY IS IT MOVING SO QUICKLY?

The magnetic field is created by the liquid outer core that starts about halfway to the centre of the Earth. You've got this large, convecting layer of liquid metal and, as it moves, it creates the magnetic field, but it also drags the field with it.

The reason the magnetic north pole is moving is because, we think, a fast jet of liquid has formed – a sort of jet stream – at the high latitudes up around northern Canada, and it's pushing the magnetic field in this area rapidly. If you look back at how the magnetic north pole has moved in the last hundred years or so, you'll see that from 1900 to 1990

the average rate of change of the pole's position was about 5 to 10 kilometres per year, and in the 1990s it suddenly started accelerating. At the moment, it's moving at about 50 or 60 kilometres per year.

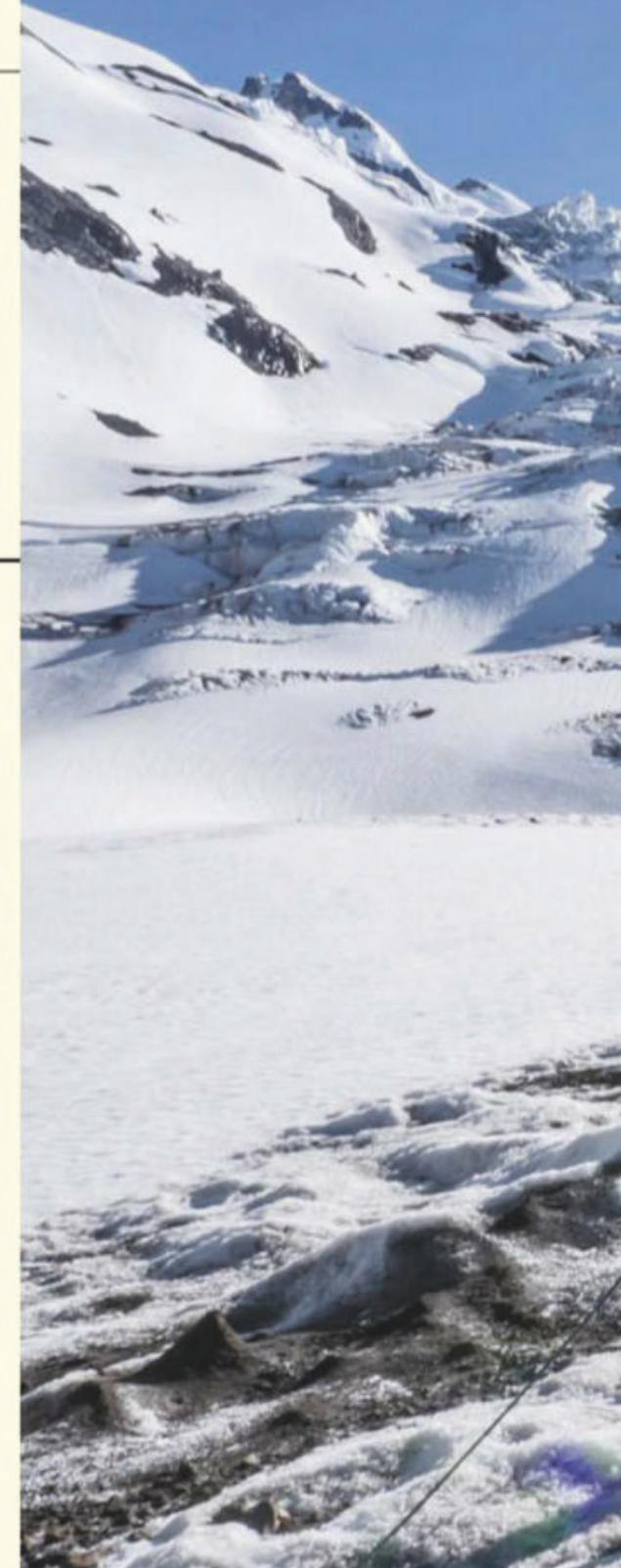
HOW'S THAT GOING TO AFFECT THE AVERAGE PERSON?

The map application in mobile phones or in-car navigation systems use magnetic field maps made by the British Geological Survey and the US National Oceanic and Atmospheric Administration. We create those maps every five years to make a prediction about how the field will change in the following five years. The last one was released in 2015. The next one was scheduled to be released in 2020, but because the magnetic north pole had moved further than we expected, by 2018 the map was already out of date. So, we were asked to update the map.

For the average person, unless you're planning to traipse around the Arctic in Canada or Siberia, you wouldn't really notice the difference, because the magnetic field maps we make for lower latitudes – below the latitude of Scotland, say – are actually fairly decent. They're not too much in error. But the maps of the high Arctic are out, because the magnetic field moved so quickly. The digital compass in your smartphone is only accurate to a degree or two, and the differences between our latest update of the map and the previous update of the map, for most people, will only be a fraction of a degree.

WHO NEEDS HIGH-PRECISION MAPS?

Mainly the people who fly aircraft over those regions. Most aircraft maps are orientated in magnetic coordinates for historical reasons, so these maps are important for aircraft, say, flying from London to San Francisco: they fly over the northern Arctic. What would happen is that the plane would drift maybe a few tens of kilometres out from where it should be, though that should be corrected by GPS. The other main users are the UK and the US military,



X

"In the 1990s, the pole suddenly started accelerating. At the moment it's moving 50 or 60 kilometres per year"



which use it in navigation systems in submarines and aircraft and so on.

HOW DO WE KNOW THE HISTORY OF THE MAGNETIC POLE'S POSITION?

Magnetic coordinates have been used for ship navigation for hundreds of years, and we've got ship records, logs and log books going back to at least the 1590s. You can use those to work out where the magnetic north was by looking at all the measurements. This tells us that from the 1500s onwards, the magnetic north pole wandered around Canada more or less in erratic zigzags. It wasn't until the 1900s that it started moving westwards, towards Siberia, and it's been accelerating that way for the last 30 years or so. Up until the 1990s, there were around 200 geomagnetic observatories where we measured the field continuously. Since 2000, a number of satellites have been launched into low-Earth orbit, up to about 400 kilometres. They fly around continuously measuring

the magnetic field and its direction.

WHY DID SAILORS START USING THE MAGNETIC NORTH POLE?

The idea was originally from Edmond Halley, of comet fame. They knew how to measure latitude, by looking at the height of the Sun in the sky, but to measure longitude was more difficult. They tried to do it by looking at the variation in the angle between true north and magnetic north – that's called declination. In 1699, Halley went out in a ship and surveyed the Atlantic Ocean and drew up the original maps of the magnetic field. When he went out and looked again, he realised that the angle had changed so quickly that his maps were out of date within five or ten years. He thought: "How is it that the magnetic field is changing?" Then he made the most amazing leap, and suggested that there must be a layer of liquid somewhere within the Earth that was causing the magnetic field to move.

He was the first person to dream up the idea of an outer core. It wasn't confirmed until 1906, by seismological data.

WHAT CAN WE EXPECT THE MAGNETIC NORTH POLE TO DO IN THE FUTURE?

We have no idea. We're like weather forecasters 100 years ago: they had a general idea which way the wind was blowing at a few points along the coast, and so made a general prediction that the wind will probably still be blowing that way tomorrow. But for us to make a detailed forecast of what will happen to magnetic north, even a few days later, is beyond our abilities, because we cannot yet measure the magnetic field at the edge of the outer core accurately enough to understand how the liquid is flowing.

DR CIARAN BEGGAN

Ciaran is a geophysicist at the British Geological Survey. *Interviewed by Sara Rigby.*



Shanghai, China

BIOLOGY

Chinese researchers clone gene-edited monkeys

Successful cloning of macaques predisposed to psychiatric disorders raises ethical questions

Chinese scientists have cloned gene-edited primates for the first time.

The team at Shanghai's Institute of Neuroscience initially used gene-editing to disable a gene in macaque monkeys that helps control their sleep-wake cycle. In humans, mutations in this gene are linked to hypertension and depression. The macaques immediately displayed sleep loss, anxiety and 'schizophrenia-like' behaviours. The researchers then cloned one of the monkeys, creating five macaques with identical genomes. To clone an animal, DNA is taken from an adult cell and placed in an egg which has had its genetic material removed. When stimulated to form an embryo, the resulting monkey is identical to the original.

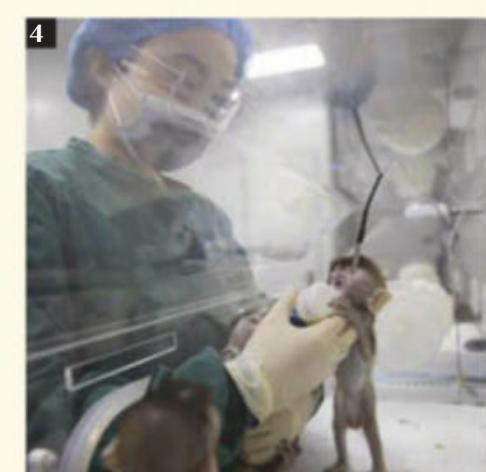
Using genetically identical animals helps scientists because it reduces variation between the individuals in experiments. It is for similar reasons that human identical twins are highly sought-after in certain types of research – you can effectively give the same person two different experiences or treatments and see what happens, knowing that the variation in results is not down to variation in genetics.

"The more like us an animal is, the better a model of us it is likely to be for research purposes," said Dr David Hunter, an associate professor of medical ethics at Flinders University, who was not involved in the research. "However it is also likely to be more like us in terms of its capabilities, and so we are more concerned about the appropriate way of treating it ethically."

Many people object to the use of primates in research. While the use of primates in research is tightly controlled in the US and Europe, the development of primate models is a national goal in China, with at least ¥25m (£2.8m) invested in the programme so far.

XINHUA NEWS AGENCY/EYEVINE X4





1. The macaques lack the gene BMAL1, which means they show signs of schizophrenia-like behaviours, anxiety and sleep loss

2. The identical macaques huddle together in their incubator

3. Researcher Zhang Hongjun holds a skull from a macaque

4. A researcher feeds the cloned macaques

5. The scientists from the Institute of Neuroscience in Shanghai at a press conference

SCIENCE BEHIND THE HEADLINES

BREAKING
NEWS

1. REVIEW

Air pollution

2. ANALYSIS

Four day working week

3. COMMENT

Screen time



1

REVIEW

AIR POLLUTION: HOW TO PROTECT YOURSELF

Ammonia from farms, factory emissions and traffic fumes can make spring the worst time of the year for air pollution

Breathing in highly polluted air can have severe consequences. In 2018, Public Health England declared that “poor air quality is the largest environmental risk to public health in the UK”. It’s estimated that exposure to outdoor air pollution contributes to the early deaths of between 28,000 and 36,000 people in the UK every year. In comparison, there were 1,793 reported road deaths in the UK in 2017.

Those who are most vulnerable to air pollution include people with cardiovascular or respiratory conditions such as asthma, the elderly, children and pregnant women. But even those who don’t fall into the most vulnerable groups will benefit from reducing their exposure to pollutants. The best long-term plan is to try to clean up the air on a global scale, but that will take a large investment of time and money. So what can we do to protect ourselves?



Buy some houseplants

Houseplants aren't just good décor: they are also a fast and effective way to clean up the air in your home. Researchers at the State University of New York studied five different houseplants to measure their efficiency at removing volatile organic compounds (VOCs) from the air. For a good all rounder, choose a bromeliad. These plants managed to strip more than 80 per cent of all pollutants out of the air over the course of 12 hours. But if you run a nail salon, try a dracaena: these removed 94 per cent of acetone, the source of the powerful smell of nail varnish remover.

Even if you're not the green fingered sort, you can always buy an air purifier to do the job instead – but make sure the device you choose is powerful enough for the size of your room.

WANT MORE?

 For more stories like this, visit our website at sciencefocus.com/realitycheck
You can also listen to podcasts with experts at sciencefocus.com/science-focus-podcast

Keep track

The best way to avoid air pollution is simply to breathe clean air. While many of us can't uproot and move to the countryside, we can at least keep track of the air quality around us. Online real-time air quality maps, like aqicn.org, use data from monitoring sites around the world to track Air Quality Index (AQI). As well as the raw data, the maps also provide colour-coded advice to help guide users. Though the data is limited by the locations of monitoring sites, the maps are still useful, especially for the most vulnerable. Some even provide a forecast.

For more detailed data, consider a personal pollution monitor, but be aware that the Air Quality Expert Group advises that personal monitoring devices aren't regularly calibrated and therefore can't provide accurate long-term data. If you live in London, consider checking the annual air pollution map for the least polluted streets and changing your commute accordingly.

Wear a fitted mask

The surgical-style mask is a common sight in smog-laden cities. But in terms of blocking particulates, these masks are shockingly inefficient. Though they filter the air, there's no effective seal around the edges, which vastly reduces their effectiveness. That's not to say that wearing a mask isn't worthwhile in general. A 2018 study from the Institute for Occupational Medicine in Edinburgh measured the efficacy of various consumer face masks and found that the key factor in reducing the inhaled particulates isn't the mask's filtration efficiency, but how well it fits.

Use green cleaning products

Think of all the different cleaning products we use around the home. Now imagine

Masks can help filter the air you breathe, but you need to ensure they fit snugly



the smell. A rule of thumb is that any product with a strong fragrance is likely to contain volatile organic compounds (VOCs). VOCs such as acetone, benzene and formaldehyde are major contributors to indoor air pollution, and can be emitted by cleaning products, paints, adhesives and anything else that relies on evaporation. Several studies have shown that regular exposure to VOCs from cleaning products – particularly for cleaning staff – can aggravate or even cause asthma.

To reduce VOC emissions in the home, choose cleaning products displaying the EU Ecolabel. These products are certified to adhere to a wide range of criteria – including limits on VOC content – ensuring that they release fewer pollutants into your home. And while you're at it, ease off the air fresheners.

by SARA RIGBY

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DISCOVER MORE



Visit the BBC's Reality Check website at bit.ly/reality_check or follow them on Twitter @BBCRealityCheck

2

ANALYSIS

FOUR-DAY WEEK: COULD WE BE MORE PRODUCTIVE BY WORKING LESS?

Some large companies are trying to increase productivity by shortening working hours without reducing pay



At the start of the year, the Wellcome Trust announced that it is considering moving all 800 staff at its head office in London to a four-day week, with no change in pay, in order to improve wellbeing and productivity. If it went ahead, it would be the largest company in the world to make this change.

The idea is inspired by smaller businesses who have reported a successful switch. Notably, New

Zealand-based company Perpetual Guardian trialled the short week with its 240 employees in spring 2018 and adopted the policy permanently in September, citing a study of the trial carried out by Auckland University.

The study found that total productivity – in terms of supervisors' assessments of performance – was maintained, but also that the employees were, on average, less stressed and more engaged, and that their work-life balance had improved.

A shorter working week could help people work more efficiently and enjoy better wellbeing

Here in the UK, workers typically fall short in productivity compared to our European neighbours. According to the latest figures from the Office for National Statistics, the average worker in Germany is just over 25 per cent more productive than the average worker in the UK, in terms of GDP per hour worked. In other words, our German counterparts have achieved more by Thursday than we manage in the whole week (show-offs).

NEED TO KNOW

The data behind the push for a four-day week

Prof Paul Redford, an occupational psychologist at the University of the West of England, says we shouldn't take these statistics at face value, however. "These overall national scores end up trying to look at cultural differences, but actually what you want to look at is organisational differences. What are the most

about 'How can I do my work in less time?' focuses people's attention on what it is important for them to do. They make slightly more strategic decisions over the actions that are going to result in higher levels of productivity," explains Redford.

The 9 to 5, five-day week is a relatively recent invention in the

"We're still, in some ways, in the tail end of a post-manufacturing industry style of working, which I think is probably not very humane, in the grand scheme of things"

successful organisations doing, irrespective of their cultures?" he says. "I don't think there's something necessarily inherent in the UK that is endemic in working practices, or the UK culture or psyche, that means that we're lazy or less productive. We may be less focused – I don't know if that's the case – but I think the way forward is to think about the organisational practices that lead to successful output."

WORK-LIFE BALANCE

Pursuit Marketing, based in Glasgow, declared Fridays to be voluntary for all staff in September 2016. Following an initial 37 per cent productivity spike, which operations director Lorraine Gray attributes to the novelty factor, total productivity settled to almost 30 per cent higher than before the change.

"I think it works really well here because it's part of an overall culture of wellbeing," says Gray. "Everyone is really clear that the focus is on the work-life balance and making sure everyone can be the best version of themselves."

Having less time to complete the same tasks compels staff to work efficiently. "Just shifting to thinking

history of human work. It was the result of much campaigning to reduce working hours once the Industrial Revolution had provided technology to vastly improve productivity. The Trades Union Congress (TUC) believes that we should once more reap the rewards of our technological boom, in particular AI and automation, and shorten our working week further.

"The Industrial Revolution, with the promotion of factory-based working, shifted the nature of work to this 9 to 5. For the most part of human history, we haven't worked to those sorts of patterns," says Redford. "We're still, in some ways, in the tail end of a post-manufacturing industry style of working, which I think is probably not very humane, in the grand scheme of things.

"I think we have an overemphasis on productivity. Sometimes the focus on wellbeing is saying that it's good to have high level of wellbeing because it's more productive; I think that wellbeing is not a bad aim in and of itself."

by SARA RIGBY

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DE-STRESS

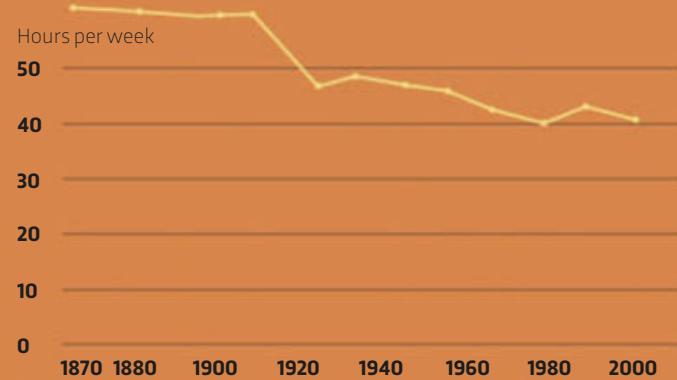
Staff at New Zealand firm Perpetual Guardian reported their stress levels decreased from 45 per cent to 38 per cent after a trial of a four-day week.

38%

9-5

New working hours

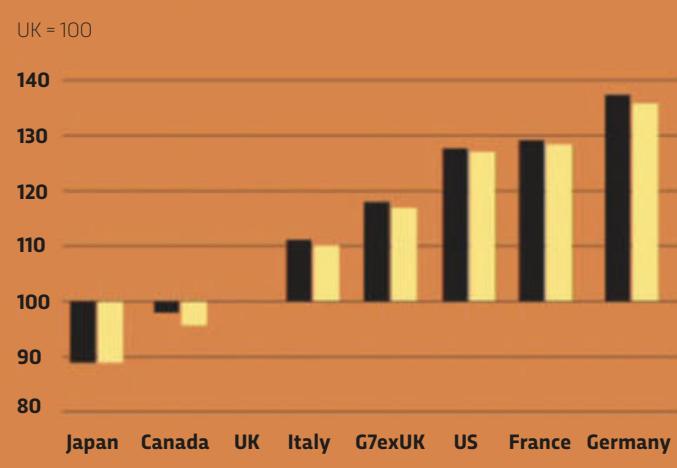
After the Industrial Revolution, our working day decreased



THE SLACKERS OF THE G7?

According to the Office for National Statistics, the UK's Gross Domestic Product per hour worked is 15.1 per cent lower than the rest of the G7, (labelled G7exUK in graph).

2015
2016



3

COMMENT

Recent reports have linked screen time to impaired development, aggression and even shortsightedness. But is there more to the story?

THE BENEFITS OF VIDEO GAMES: WHY SCREEN TIME ISN'T ALWAYS BAD

We live in a society where we're surrounded by screens. For the first time in our history, we have access to all human knowledge at the touch of a button; screens are our work, and also our play. But they're also increasingly becoming the source of our fears and worries. Whether it's poor mental health, sleep deprivation or social isolation, staring at screens, so the headlines go, is intrinsically, unequivocally, bad for us.

When you dig into the research, however, a subtler story emerges. A recent study at Oxford University suggested that if you were to tell a researcher how much time you spend on screens, it would only allow them

To an outsider, gaming looks like an isolating, antisocial pastime. But it can bring people together and help those with mental health conditions





X

“It’s important we don’t vilify screens and video games to the point that we end up shutting out the ways in which they can enrich our lives”

to predict less than half a per cent of your wellbeing. To put this into perspective, the team found that eating potatoes had about the same effect on wellbeing as screen time. The links between screen use and mental health don’t seem to be anywhere near as strong as we might think. In fact, some research has shown that, when it comes to kids’ wellbeing, some screen time is better than none at all.

For the past few years, I have been researching the effects that one type of screen time has on our behaviour: playing video games. It’s easy to see why video games are often dismissed as an antisocial pastime. Players seem absorbed by the action on the screen, as if the rest of the world doesn’t exist. Without further context, it’s hard not to see games as anything other than digital junk food.

But context matters, and understanding the experience of the players can give us new insights. Video games are an inherently social experience: since their inception, they’ve been designed as cooperative and collaborative experiences. Take *Minecraft*, for example. It may seem like a fairly isolating, single-player experience to the outsider, but it brings people together in all sorts of ways. Some play to connect with their friends, others share in the creative experience of building something monumental, and it’s even been used as an interactive tool to teach students basic chemistry (see the University of Hull’s

MolCraft project). Elsewhere, studies have shown that video games can be used as therapeutic interventions to help soldiers overcome PTSD, and to help children with cancer stick to treatment regimes.

As for the supposed negative aspects of video games, the story is largely the same. Studies that show a link between violent games and aggressive behaviour are often picked up in the news over other, more robust studies. Part of the problem is that it’s remarkably hard to test for aggression in the lab, and there’s also a great deal of flexibility in the way that researchers can analyse their data. But where the best methods are used, evidence suggests that playing violent games has fairly negligible effects on our behaviour.

Our understanding of the behavioural effects of video games – and screens more generally – isn’t yet complete. After all, these technologies are a relatively recent addition to our lives. But while we wait for more conclusive answers, it’s important that we don’t vilify screens and video games to the point that we end up shutting out the multifaceted ways in which they can enrich our lives. Like many things, we can use them in good ways, and we can use them in bad ways. It’s up to us, as a society, to harness their potential for good.

by DR PETE ETCHELLS (@PeteEtchells)
Dr Pete Etchells is a psychologist at Bath Spa University and author of *Lost In A Good Game* (£13.64, Icon Books).

FOLLOW THE CONVERSATION

@ShuhBillSkee



Prof Andy Przybylski is the director of the Oxford Internet Institute. His research has been used to inform government reports on screen time effects.

@OrbenAmy



Amy Orben is a PhD student who researches effects of screen time on behaviour and mental wellbeing using large datasets.

@CJFerguson1111



Prof Chris Ferguson’s research largely shows that violent video games have negligible effects on our behaviour.

@DrKowert



Dr Rachel Kowert is a psychologist and video games expert who has produced an excellent parents’ guide to understanding the effects that video games can have on us.

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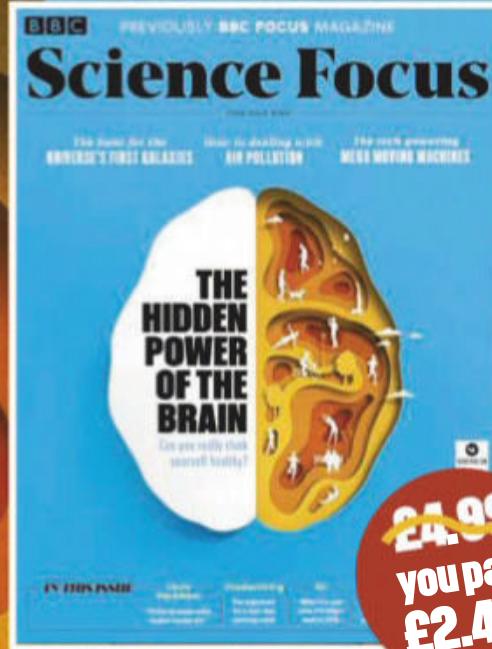
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MONSTER MOVERS

Think moving house is difficult? Take a look at the gargantuan machines that are needed to move rockets, wind turbines, Antarctic bases and even entire buildings

Words: HAYLEY BENNETT

SNOW EASY TASK

← HALLEY ANTARCTIC RESEARCH STATION

'Big Red' is the affectionate name for the main living area in the British Antarctic Survey's Halley Research Station. It houses a dining room, kitchen, walk-in fridge, lounge, gym and a small bar. Empty, it weighs about 220 tonnes. In early 2017, when the entire station had to be moved 24km east (due to a crack in the Brunt Ice Shelf on which it sits), Big Red was one of the largest items on the shift list. Moving it required two bulldozers as well as a 'snow groomer' called a PistenBully, and took almost five hours. Now back at their relocated base, Halley researchers continue to monitor the cracks in the ice shelf, study polar climate change and search for Antarctic meteorites.

A STELLAR JOB

↓ ALMA TELESCOPE ANTENNA

Astronomers in the Atacama Desert, Chile, are observing nearby galaxies to understand how stars are formed. Their work wouldn't be possible without the help of ALMA, the Atacama Large Millimeter/submillimeter Array, whose 66 separate antennas are spread across the Chajnantor Plateau, 5km above sea level, to form a giant telescope. The antennas don't stay put, though; they're constantly being moved around – at a rate of about three a week – to bring different celestial objects into focus. "Astronomers request their preferred telescope configurations based on the resolution and field of view of the targets they want to observe," says Dr Norikazu Mizuno, ALMA's head of engineering. In the image below, an antenna travels aboard 'Lore', one of two 20-metre-long transporters used to reposition the antennas. It's a slow process though – when they're loaded down like this, the transporters can only trundle along at 12km/h (7mph).

HITCH A LIFT (OFF)

NASA'S MOBILE LAUNCHER →

A truck sprays water to keep the dust down as NASA's latest rocket launch tower is moved to Launch Pad 39B at the Kennedy Space Center, in Florida. This 115m-tall mobile launcher is currently undergoing testing. In the coming decade, it will provide pre-launch power, communication and electrical connections to NASA's much-anticipated Space Launch System (SLS) – a next-generation rocket that will be powerful enough to take crews to Mars.

The vehicle that's transporting the launch tower is one of NASA's two 'crawler-transporters', which have been carrying rockets and spacecraft to the launch pads here for over 50 years. True to their name, these travel at a top speed of about 1.6km/h (1mph). The crawler in this picture (opposite) has recently been modified so that it can lift over 8,000 tonnes, making it strong enough for the hefty technology that will take humans further from Earth than ever before.



ESO, NASA/JPL





ROCKET EXPRESS

↑ SOYUZ-FG ROCKET

At the Baikonur Cosmodrome in Kazakhstan, it's traditional to place coins on the train tracks when a rocket is being transported. The diesel-powered train crushes them as it crawls to its destination. Next stop for this Soyuz-FG rocket is the launch pad – the same one that witnessed Yuri Gagarin lift-off for the first manned space flight in 1961.

Two days after this photo (above) was taken in March last year, the rocket ferried two US astronauts and one Russian cosmonaut into space, where they boarded the International Space Station (ISS). Most ISS launches now take place at the Cosmodrome after NASA closed down the Space Shuttle program in 2011. This Russian spaceport was initially built by the Soviet defence ministry in 1955 as a launching ground for ballistic missiles and was chosen because of its rail links. Today, the old train tracks provide a handy way to cart around these 305-tonne rockets.

MONUMENTAL SHIFT

ARTUKLU HAMAM BATHHOUSE →

This centuries-old, 1,500-tonne bathhouse (opposite) is relocating to an archaeological park outside the historic town of Hasankeyf, Turkey. The aim is to save it from the waters that will engulf Hasankeyf when the recently completed Ilisu hydroelectric dam is flooded.

Stabilised on a concrete platform, the bathhouse inches along on a 256-wheeled vehicle, taking over nine hours to travel just three kilometres. Thought to be at least 650 years old, it's not the only monument being relocated – others include the tomb of Zeynel Bey (son of a 15th-Century leader) and a disassembled mosque.

It may sound impressive, but the move has been controversial. "The transferred monuments are cut from their foundations and moved to a site where they do not belong," says Prof Dr Zeynep Ahunbay, an architectural historian at Istanbul Technical University. Activists at Hasankeyf say that the movement of the monuments has been carried out without proper consultation of the community or experts. For now, filling of the dam remains on hold since water shortages in 2018.

IT'S A BREEZE

WIND TURBINE →

If you don't have a vehicle large enough to transport your wind turbine, Scheuerle will make one for you. Since the 1970s, this German company has been building 'self-propelled modular transporters' (SPMTs) capable of carrying the world's heaviest loads, from ships to satellites. These wheeled platforms are pieced together from smaller units, connected side-by-side or end-to-end, and sized especially for the job in hand.

In the seaport of Eemshaven, Netherlands, these wind turbine sections (right) are being transported in an upright position, meaning that a more compact SPMT can be used. The SPMT built for the job combines four units to spread the load over 12 parallel axles, all of which can be controlled remotely, and separately, for precision steering. Theoretically, though, there's no limit to the number of axles that could be used if you wanted a super-sized version. **SF**

by HAYLEY BENNETT (@gingerbreadlady)
Hayley is a Bristol-based science writer and editor. She is the co-author of *The Big Questions In Science* (£5.99, Andre Deutsch).





THE HUNT FOR THE OLDEST GALAXIES IN THE UNIVERSE

A region of Abell 1758, a massive galaxy cluster photographed by the RELICS project

The deeper we look into the vastness of space, the further back in time we are able to see. Now, NASA's RELICS project is pushing this phenomenon as far as it can in an attempt to observe galaxies that formed at the very beginning of the Universe

by MARCUS CHOWN
(@marcuschown)

As the fireball of the Big Bang expanded and cooled, it went from white-hot to cherry-red before finally fading into invisibility. The Universe was plunged into blackness and the resulting cosmic dark age stretched on interminably. Over time, the Universe doubled in size, doubled once more, over and over again, then, one day, something extraordinary happened. The dark age came to an end. Across the entire length and breadth of the Universe, stars began switch on like lights on a Christmas tree.

The first stars either came together under gravity to create the first galaxies, or were actually born in the clouds of gas and dust that made up the first galaxies. And the hunt to find these first galaxies is hotting up. One project – the Re-ionization Lensing Cluster Survey (RELICS) – has found around 300 galaxies that existed in the first billion years of the Universe's history. One galaxy in particular is so old that the Universe it occupied was a mere 3 per cent of its present age of 13.82 billion years. Such objects appear in astronomers' telescopes like persistent after-images, their light

having travelled across space for billions upon billions of years before reaching us.

BACK IN TIME

More than 40 astronomers in many countries have been involved in the RELICS project, contributing hundreds of hours of observing time on the Hubble Space Telescope and the Spitzer Space Telescope. However, the principal observing instrument is the Universe itself. The gravitational fields of the massive clusters of galaxies that pepper the Universe act like giant lenses that focus and magnify the light of more distant galaxies that are often far too faint to see by any other means. "We take advantage of nature's own telescope," says Dan Coe, principal investigator of RELICS at the Space Telescope Science Institute in Baltimore.

To find the useful lensing clusters that would help him spot the oldest galaxies, Coe searched through Hubble's archive of images and a recent catalogue of around 1,000 galaxy clusters observed by the European Space Agency's (ESA's) Planck satellite. Planck's principal purpose was to image ➤

COSMIC TIME

0

 10^{-36} to 10^{-32} secs

1-10 minutes

380,000 years

Cosmic timeline

The Universe,
from the Big Bang
to today

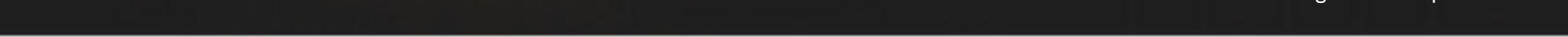
COSMIC EVENT

Moment of creation.

Universe 'inflates', increasing in volume by a factor of 1 followed by 26 zeroes in a fraction of a second.

Light elements such as helium are made.

First atoms form. Universe goes from opaque to transparent. Matter begins to clump.



the cosmic background radiation – the ‘afterglow’ of the Big Bang fireball itself – but the ‘far-infrared’ light it picked up also comes from warm dust in galaxy clusters. “We ended up with 41 massive galaxy clusters,” says Coe. “We selected them for their extreme mass, which makes them enormously powerful gravitational lenses.”

In the immediate neighbourhood of each cluster are literally thousands of ghostly images of distant galaxies that by chance have been ‘gravitationally lensed’ by the cluster. But most are of galaxies that are not at great distances,

and so not in the very early Universe. “The trick to finding truly ancient objects is to look for lensed galaxies that appear in infrared images from Hubble and Spitzer images, but not in Hubble images taken at visible wavelengths,” says Coe. But to understand *why* this reveals ultra-distant, ultra-early galaxies, we need to look at the concept of ‘redshift’.

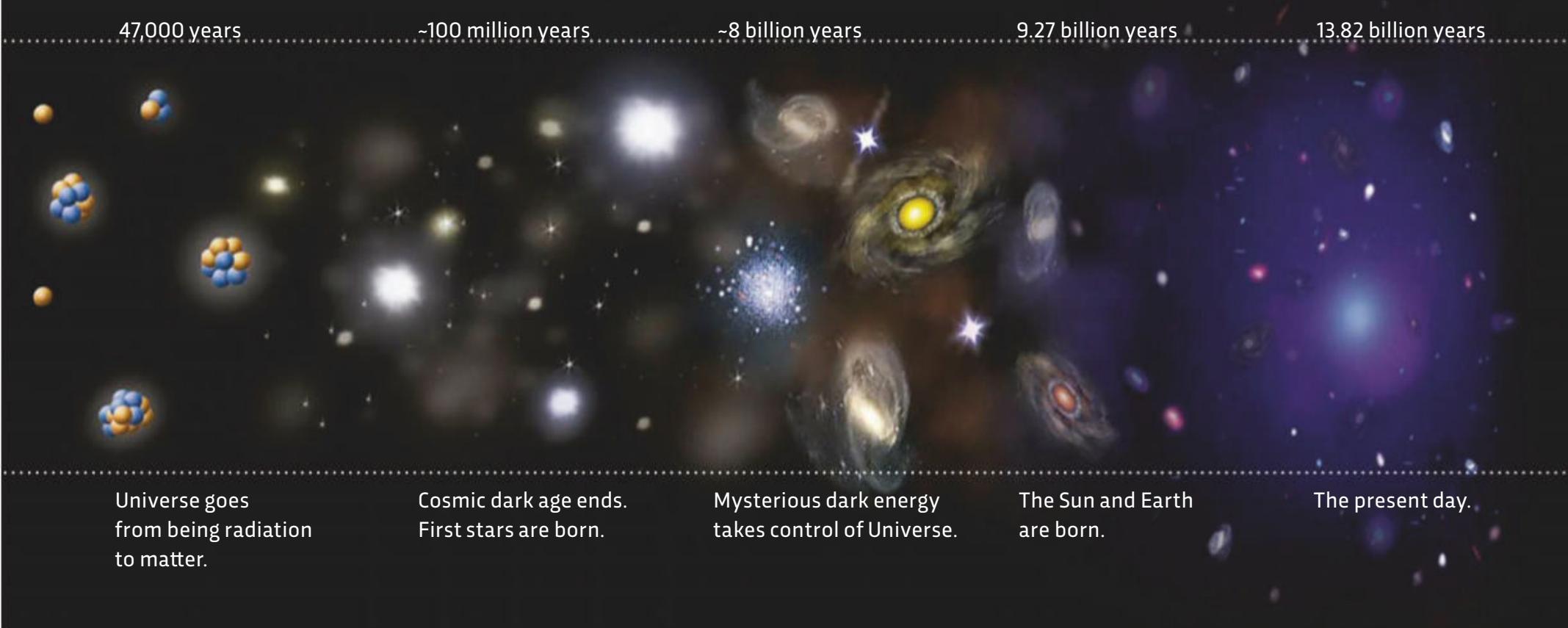
SEEING RED

When the Universe was younger, it was smaller. The most distant galaxy in RELICS existed more than 13 billion years ago when the Universe was less than one-thousandth of its current size. As space expanded over that time, it also stretched the light from that galaxy. Since red light has a longer wavelength than blue light, the light of such galaxies is shifted to the red end of the spectrum, or ‘redshifted’.

The light of the earliest galaxies has been so severely redshifted that its visible light now appears as ‘infrared’, at wavelengths beyond the red end of the spectrum. Thus, the galaxies have the unique characteristic of being invisible to Hubble’s Advanced Camera for Surveys but visible to Hubble’s Wide Field Camera 3, which is sensitive to infrared light. Spitzer’s infrared imaging instruments are also important in determining whether galaxies are at extremely high redshift, or less distant and merely intrinsically red due to dust or old age.

The gravitational lens formed by a galaxy cluster zooms in on a tiny region of the night sky so it might be expected that such a region would be more likely to contain empty space than any galaxies in the distant Universe. However, it turns out that galaxies in the early Universe were much smaller and a lot more numerous, so actually there is a good chance of them appearing in the field of view of any given gravitational lens. This explains why RELICS has found not a handful of galaxies, but around 300. These date back to the first billion years of the Universe and include the brightest ones ever observed from that epoch.

“THE MOST DISTANT GALAXY IN RELICS EXISTED OVER 13 BILLION YEARS AGO”



Among the 300 galaxies is the rather unimaginatively named SPT0615-JD. It has a redshift of 10, which means it existed when the observable Universe was less than one-tenth of its current diameter and only about 400 million years old (the current record-holding galaxy, found in a previous survey, actually has a redshift of 11). The lensing effect has distorted the galaxy into an extended ‘arc’ and Coe says further observations will be needed to discern any details. Nevertheless, it is already obvious that SPT0615-JD is quite unlike a present-day galaxy. It is only one-

BELOW

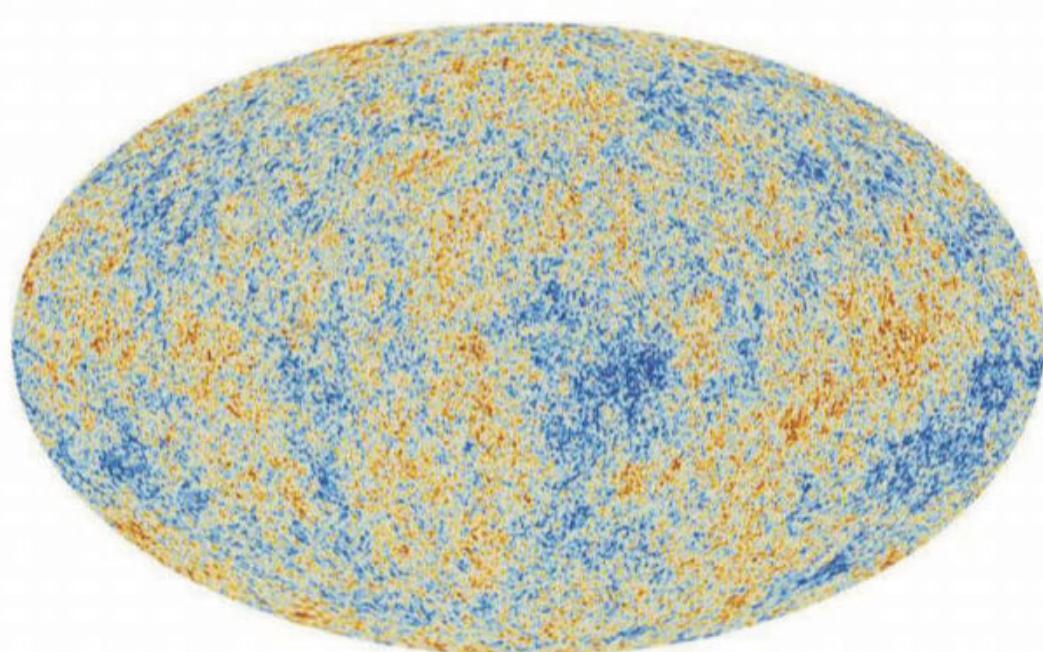
Oval sky map of the cosmic microwave background (CMB), as seen by the Planck satellite. The CMB is radiation left over from shortly after the Big Bang. The different colours are tiny temperature differences, due to density variations after the Big Bang. Denser regions attracted more matter, leading to the formation of galaxies

twentieth of the diameter of the Milky Way, has less than one-hundredth of its mass, and none of its regularity. In fact, Coe and his colleagues refer to it as a ‘smudge’. The other 300-odd galaxies are similarly small.

If we had a time machine and could go back to a redshift of 10, we would find ourselves in a different Universe. There would be no galaxies with distinct structures like today’s ‘giant ellipticals’ and ‘spirals’. In their place we would see tiny, disordered blobs, often less than one-hundredth the diameter of the Milky Way. Such galaxies would be undergoing star formation at a ferocious rate, often hundreds or thousands of times faster than galaxies in today’s Universe. There are at least two reasons for this. First, gas – the raw material of stars – was plentiful. Second, galaxies at a redshift of 10 were thousands of times more numerous than today’s galaxies and far closer together, resulting in frequent collisions and mergers, which triggered intense bouts of star formation.

The fact that mergers were such a dominant feature of the early Universe may tell us something important about the galaxies of that time. “Very possibly, we are seeing the building blocks of today’s galaxies,” says Coe. “As time passed, these ancient galaxies were destined to collide and merge over and over again. In fact, our Milky Way could well have undergone thousands of such mergers to reach its current size.”

According to Coe, we have not yet seen the first galaxies, since even the earliest galaxies we’ve found contain older, bright red stars that are near the end of their lives. The first galaxies could conceivably have formed a mere 200 million years after the Big Bang. The best hope of finding them, says Coe, is by using the James Webb Space Telescope, the successor ➤

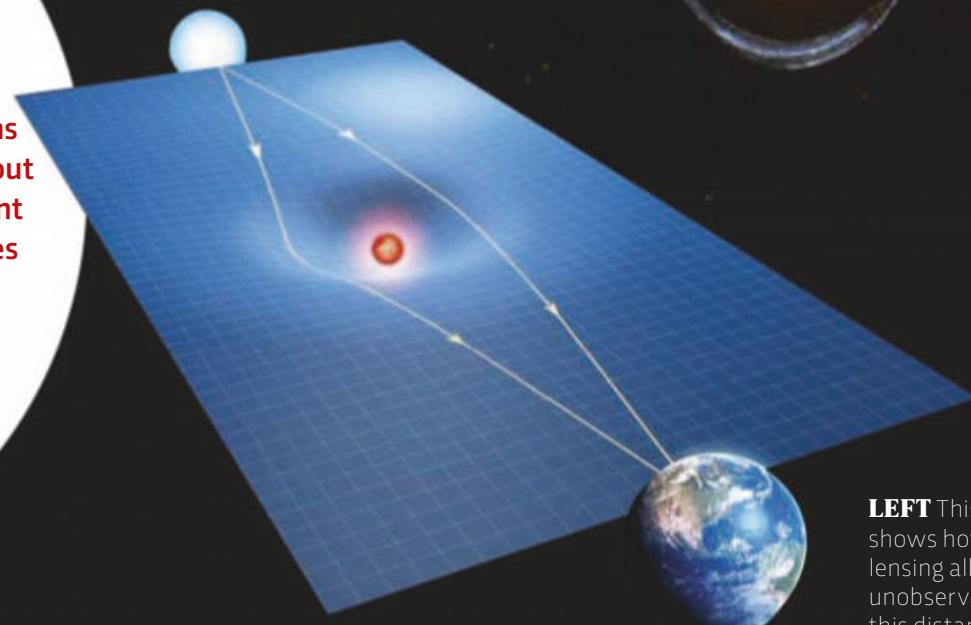


GRAVITATIONAL LENSING

HOW IT WORKS

Gravity bends the path of light, and was predicted by Einstein's General Relativity in 1915. Arthur Eddington confirmed it during a total eclipse of the Sun in 1919. Light-bending by gravity, now known as gravitational lensing, means that much of the distant Universe that we see without telescopes is an optical illusion. As light from distant galaxies travels towards us, it passes closer galaxies and is bent and focused. Sometimes this creates distorted arcs of the distant galaxies, sometimes multiple images. Such lensing acts as a telescope, enabling us to zoom in on bits of the Universe we would otherwise be unable to see.

RIGHT The gravity of a red galaxy has distorted the light from a more distant blue galaxy, causing it to curve around



LEFT This illustration shows how gravitational lensing allows us to see unobservable objects, like this distant blue star

of Hubble, which is due for launch in 2021. With its 6.5-metre primary mirror, it will orbit around the Sun at the so-called Lagrange-2 point, about a million kilometres from the Earth. Lagrange points are areas in space where gravity from the Sun and Earth balance out the orbital motion of a satellite. Placing a spacecraft at any

of these points allows it to stay in a fixed position relative to the Earth and Sun with a minimal amount of energy needed to change its direction.

DIGGING DEEPER

As James Webb will be sensitive to far-infrared light, it will be capable of detecting galaxies at ultra-high redshift. The hope is that the James Webb will shed light on 'cosmic re-ionisation', a key event which fundamentally changed

the nature of the gas floating throughout space in the early Universe. About 380,000 years after the Big Bang, the fireball had cooled sufficiently for electrons to combine with hydrogen and helium nuclei to form the Universe's first atoms. However, there is a mystery. Today, when astronomers observe the hydrogen gas floating in space, they discover that its electrons have been blasted away – it has been 're-ionised'. The only thing that could have re-ionised the Universe is high-energy ultraviolet light. So where did it come from?

Planck observations indicate that re-ionisation began at a redshift of about 9. One possibility is that the responsible ultraviolet light came from the first stars, which may have started forming just 100 million years after the birth of the Universe. Another possibility is that the ultraviolet light came from matter heated to incandescence as it swirled down onto supermassive black holes. These formed in the hearts of newborn galaxies, causing them to shine as super-bright quasars. Coe thinks it's possible that multiple sources re-ionised the Universe. "Maybe stars are responsible for most of the re-ionisation and quasars for some,"

BELLOW Supermassive black holes, like the one in this illustration, may have played a key role in transforming the nature of gas in the early Universe



RIGHT Engineers assemble the primary mirror of the James Webb Space Telescope, due for launch in 2021



he says. "And it is even conceivable that there might be another source – perhaps the annihilation of particles of dark matter, mysterious invisible stuff known to outweigh the stars and galaxies by a factor of six."

But the hope is that James Webb will help answer many more. Like when did the first stars form? Such Population III stars, as they are known, would have contained only hydrogen and helium from the Big Bang but no heavier elements such as oxygen and calcium and iron, which can be made only by nuclear reactions inside stars. Nobody has yet spotted any Population III stars, which are expected to have been much more massive than today's stars and raced through their lives at breakneck speed in only a few million years before detonating as supernovae.

Hubble has already spotted galaxies making the transition from amorphous blobs to ordered structures, rotating like the great spiral of the Milky Way, but James Webb may find the earliest galaxies that exhibited such ordered rotation. In fact, there is a possibility that Coe and his team may be able to determine this with follow-up observations using the Atacama Large Millimetre Array in Chile. If they can detect emission from oxygen in any of their ancient galaxies, differences in the frequency of that emission across the galaxies could reveal whether some parts are moving towards us and some away in a systematic way. Such a doppler effect is the smoking gun for galaxy rotation.

James Webb may settle other questions, such as when did the first galaxies form? What did they look like? Are they truly the building blocks of galaxies like the Milky Way? "We have observed galaxy evolution over 13.4 billion years of cosmic time – that's 97 per cent of the way back to the beginning," says Coe. "I am most excited to see the missing 3 per cent – the last remaining jigsaw piece." **SF**

"THE JAMES WEBB TELESCOPE MAY ALSO SETTLE OTHER QUESTIONS, SUCH AS WHEN DID THE FIRST GALAXIES FORM?"

by MARCUS CHOWN (@marcuschown)

Marcus is the author of *Infinity In The Palm Of Your Hand* (£14.99, Michael O'Mara Books).

INTERVIEW

DOGGED CRUSADER

Chris Packham jets off to Mexico this month to present the BBC's Blue Planet Live. He tells Helen Glenny about his fight to fix the planet, his kinship with Alan Turing, and dissecting Donald Trump

YOU'RE PRESENTING *BLUE PLANET LIVE* WITH LIZ BONNIN AND STEVE BACKSHALL THIS MONTH. WHAT'S THE PLAN?

There are two objectives: we want to engage the audience, and we need to get close to the animals and be able to tell their stories. We're also doing an overview of oceanographic health. For instance, the Japanese have said they're going to resume commercial whaling in their own waters. I thought, Japan, relatively small island, so the waters they have control of will be relatively small. But I was wrong. They cover an area the size of India, and within that area there is an extraordinary diversity of whales.

These sorts of issues, whether it's welfare, exploitation, overfishing, pollution, plastics, will all be on our agenda.

WHERE WILL YOU BE PRESENTING FROM?

I will go to Baja California, in Mexico. It's quite remote. Because it's equatorial, nature there has a high diversity and productivity – lots of turnover. Last time I was there we went out one night looking for squid, and a school of pilot whales went by and half an hour later they were still coming past. We couldn't believe it. There were thousands of these animals in this school.



DO YOU THINK ABOUT BALANCING ENVIRONMENTAL PROBLEMS WITH THE POSITIVES ABOUT NATURE?

You can't be all doom and gloom. Firstly, people have got to care, and then you've got to make them want to take action, and they're only going to care if they are entranced by it. I'm trying to leave this planet in a slightly better state than it was when I arrived, and at the moment I'm losing very badly, so I'm trying ever harder to achieve that objective.

DO YOU THINK THAT'S SOMETHING WE'LL BE ABLE TO ACHIEVE?

I think we will suffer some very sad losses, and we will continue to make some poor mistakes. But ultimately, we are a resourceful, adaptable, intelligent species, and when it comes to the crunch, I think we've got the toolkit and the people to turn it around.

WHAT NEEDS TO CHANGE?

For me, there is no ambiguity about the fact that continued economic growth is the fastest route there is to global catastrophe. We cannot

“I think we will suffer some very sad losses... but when it comes to the crunch, I think we've got the toolkit and the people to turn it around”



Chris Packham
has called his
poodle, Scratchy,
the centre of his
universe

• continue to entertain that sort of growth, because it's fuelled by consumption of the Earth's resources. This model of thinking – that everything has to be a growth progression – is entirely fallacious, and it's come to the point now where it's downright dangerous. That really, really worries me.

[Politicians] need a far greater awareness of the environmental imperilment of the planet. And I say 'planet' because we're one species on one planet with one problem. We separate ourselves with flags and lines on the ground, but there's no time for that any more.

DONALD TRUMP DOESN'T SEEM TO APPRECIATE HOW BAD A STATE THE PLANET IS IN. WHAT WOULD YOU SAY TO HIM, GIVEN THE CHANCE?

I'd want to find out the truth about what motivates him. Does he genuinely believe what he says, or does he have another motive?

I need to scientifically analyse Donald Trump. I want to know why he feels that way. How did he get to that point where he wants to build a wall? How did he get to the point where he's deconstructing environmental legislation all across America, with catastrophic results?

The other thing is that people with Asperger's are typically very, very manipulative. Not in a nasty way, but we see things in detail, we watch people in detail, and we learn a lot about them, and then we use that knowledge to get them to do what we want. That's the approach I would take. I wouldn't spend 10 minutes shouting at Donald Trump. That's what everyone else is doing, and it's clearly not working. I'd spend 10 minutes trying to understand what makes him tick.

WITH ALL OF THESE THINGS GOING ON, WHAT KEEPS YOU AWAKE AT NIGHT?

Our greatest worry of all is human population growth, in my opinion. Climate change is going to make life hell, and it's going to have disastrous consequences, but I think that as a species, we are so adaptable and innovative and intelligent that we will cope with that. It won't be comfortable, I'm not saying it's going to be great.

What we can't cope with is that there are just too many of us. Because if you run out of resources, it doesn't matter how well you're coping: if you're starving and thirsty, you'll die. So we've got to start talking about this.



1

"I wouldn't spend 10 minutes shouting at Donald Trump... I'd spend 10 minutes trying to understand him"

HOW WOULD YOU TACKLE THAT PROBLEM?

The first thing I'd do is globally emancipate and educate women. In every situation where that has happened, we see women get married later, and they have fewer kids. Think of all the countries around the world where women cannot access education, careers and equality. That would make a profound difference.

For filming, I went to a slum in Nigeria where only 10 per cent of the kids were in any form of education, and the education by our standards was rudimentary. We met three young women there who had come out of the most abject poverty you can imagine, and they were at university. I asked them, were they married? No. They all laughed. That's crazy. And I asked them how many kids they might have if they start a family? They said two, three. As opposed to the 10 that some women there are having. Speaking to those young women was just brilliant. They'd fought against misogyny and chauvinism to get an education, and it was paying dividends for them. There are women all over the planet that could do that if we gave them the chance.

1. Baja California in Mexico is a great place to see whales in all their glory

2. A minke whale caught as part of Japan's 'research' whaling program. The country has announced plans to resume commercial whaling in July

3. Filming in Makoko, Lagos, Nigeria, for a new BBC documentary called *Population With Chris Packham*



2

GETTY IMAGES, BBC X2



3

LAST MONTH YOU GAVE A SPEECH ABOUT ALAN TURING FOR BBC'S *ICONS*. WHY DID YOU WANT TO SPEAK ABOUT HIM?

Firstly, he was a scientist, and I think that science has been disregarded recently. There are people saying they have had enough of experts, but I firmly believe that we should be listening to the scientists.

My father's a keen military historian, so I've known of Alan Turing from a young age. We can't give retrospective diagnosis, but it's highly likely that Turing had Asperger's, so there's a sort of kinship between us. I had read a few books about his life before we did the programme, and there were parallels with my own. He was bullied at school, he was ostracised, he found it difficult to fit in socially. The additional burden that he endured was that he was homosexual at a time when homosexuals were ruthlessly persecuted. And yet he still demonstrated extraordinary genius.

Then the tragedy is that society basically brutalised him and betrayed him. There's a sense of guilt about that, and I think it's warranted. The thing about people like myself, people with Asperger's, we hate injustice. We hate personal injustice particularly. So I really felt the injustice that had been wrought upon Alan Turing. It was something that angered me and motivated me and shamed me.

MANY PEOPLE ON THE AUTISM SPECTRUM MAKE VALUABLE CONTRIBUTIONS TO SCIENCE...

Yes, and I agreed to do the *Asperger's And Me* programme on the basis that we celebrate my type of autism. There are many people with that condition who are capable of achieving great things.

One of the other aspects of the condition is that we don't care what other people think quite as much, so we take risks. We say what we think, we tell the truth, even if it's hard for other people to hear. And I think that for people with Asperger's, there's no box. We don't see any boundaries. Turing didn't see that there was any issue over cracking the enigma code – it was just a question of how to do it. I think that, in the modern world, that is something extremely valuable.

I was really keen for both of these programmes [*Asperger's And Me*, and *Icons*] to speak to young people who are in the most desperate stages of dealing with the condition, in their teens and early 20s. That's when they are in education, when they might have an aptitude for science. It's very important to say: "We believe in you. We know that you've got skills. It doesn't matter that you can't socialise, or that you don't want to socialise, or you're clumsy, or you can't interpret this, that and the other. There are things that you can do that no one else can. You must embrace the good parts of your life."

I had no one telling me that when I was young, and it made my life very, very difficult. I thought that I was broken. So, I'm keen to say, "Look, we need you, and we will make the world work for you, and it will be mutually advantageous." SF



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COMMENT

IT'S TIME TO TAKE A STAND

It turns out that getting up off your backside can really improve your health

I used to write articles like this one while sitting, slumped at my desk. Things changed at Christmas, when I was given a standing desk. My wife, Clare, decided my posture was terrible, and that although I intend to get up every 30 minutes and roam around, once I've sunk into my chair I rarely do.

Many of us sit too much. We sit at work, in the car and at home, moving only to shift from one seat to another. Even if you exercise regularly, there is mounting evidence that it will not undo the damage done by prolonged sitting. So why is sitting so damaging? One thing it does is change the way our bodies process sugar. When you eat anything containing carbs, your body breaks it down into glucose, which floods your blood. Your pancreas then produces insulin to get your glucose levels back to normal, but how efficiently your body does that is affected by how physically active you are.

On *Trust Me, I'm A Doctor*, we joined forces with Dr John Buckley from the University of Chester to conduct an experiment. We asked 10 people who worked at an estate agents to stand for at least three hours a day for a week. Some embraced the idea, others were worried that it would hurt their backs. A number of them felt they would not be able to stick to it. But they managed it.



X

"If you stand for three hours a day for five days, that's an extra 750 calories burnt"

We fitted them with accelerometers so we could record how much they were moving. They also wore heart rate trackers, and had glucose monitors that measured their blood sugar levels. The researchers took measurements on days when the volunteers stood, and when they sat. There were some striking differences. As we had hoped, blood glucose levels fell back to normal after eating far more quickly on the days when the volunteers stood than when they sat.

There was also evidence that by standing they were burning more

calories. "If we look at the heart rates, we can see they are on average around 10 beats per minute faster when standing, and that makes a difference of about 0.7 of a calorie per minute," Buckley said.

Although that doesn't sound like much, it adds up to about 50 calories an hour. If you stand for three hours a day for five days, that's an extra 750 calories burnt, or around a kilo of fat. Buckley thinks that although exercise offers many benefits, our bodies need the constant, almost imperceptible increase in muscle activity that standing provides. Simple movement helps us to keep our blood sugar under control.

I am adjusting well to my new desk. I am now standing for an extra four hours a day and feel more productive. While we can't all stand up at work, small adjustments, like going to talk to a colleague rather than emailing, should help. SF



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).



COMMENT

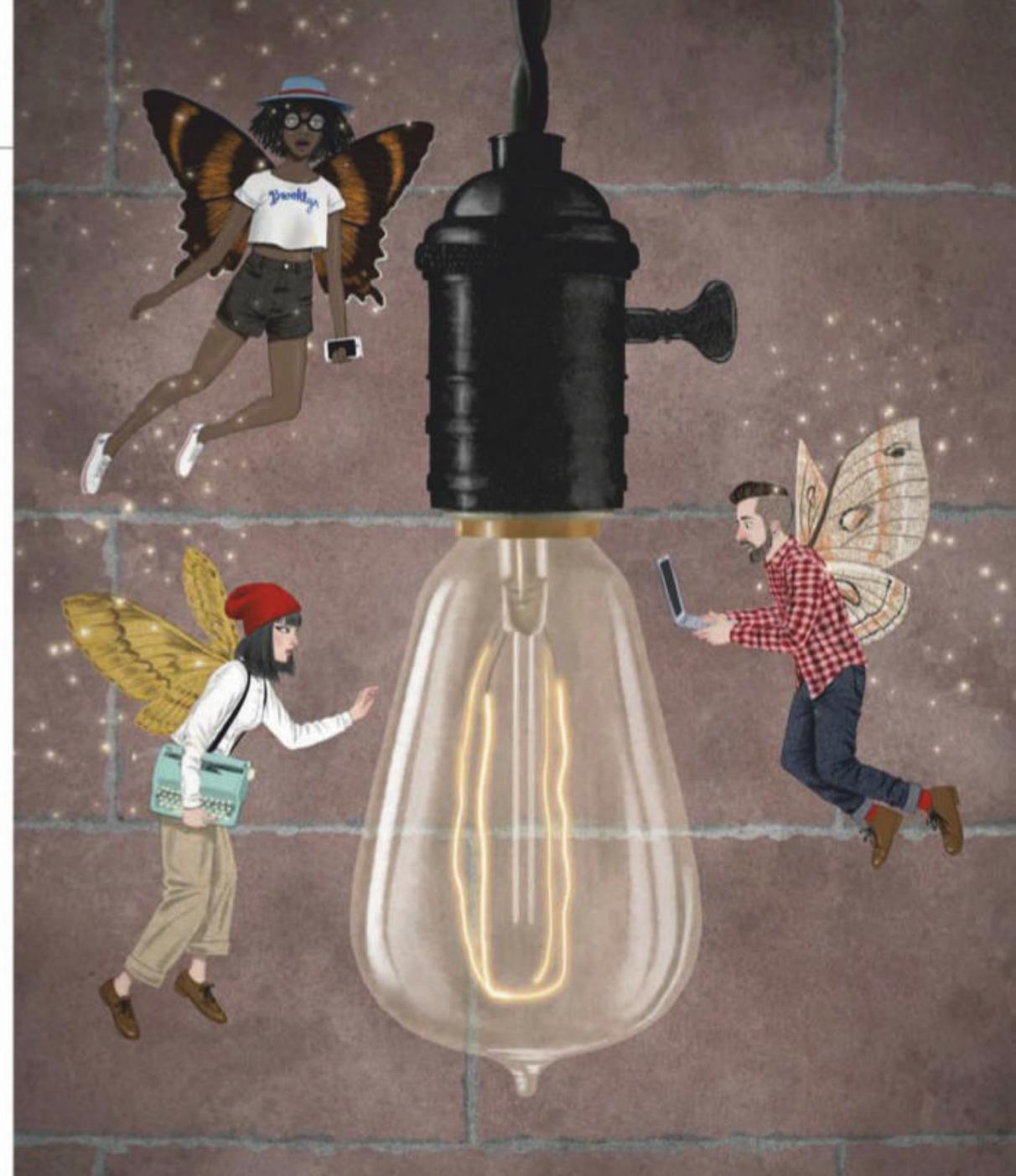
BRING ON THE BLAND

Our love of online sharing is making everywhere a bit, well, samey. And we only have ourselves to blame



**ALEKS
KROTOSKI**

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.



It's 2011. I'm in New Zealand for the first time, speaking at a literary festival about my most recent book. I'm discombobulated. I'm hungry for something familiar. Something to make being this far away feel okay.

I loaded up the recently launched Google Now on my phone. It read my location, the weather and time. It compared that information with what it knew I liked based on past searches, and predicted what it thought I might like, based on search results of people similar to me.

When I arrived at the suggested cafe, it was exactly in my comfort zone: exposed brickwork, white subway tiles, lots of greenery, bare wood tables, Edison bulbs. I had to wait for a table, so I dived into a book that I'd brought along for the ride. Immediately, I started chatting about the book with the person next to me (nice shirt). He and his girlfriend (great socks) had read it, and wasn't it great, and where are you from, et cetera, et cetera.

Soon, we discovered we knew the same person back in London. Small world, eh? You could revel in the connectedness of humans, of the tenacity of people to discover

X

"He could drink coffee in cafes that looked the same – complete with cookie-cutter tattooed baristas"

commonality. You might take another view, and think it's suffocating, that there's nowhere to escape the mobile middle classes. Or, you could say that I was a pioneer in a new land, unlimited by geography. Author Kyle Chayka calls it the land of AirSpace.

Chayka is a Brooklyn resident who made his first foray into AirSpace around the same time as I did, when he stayed in an apartment in the heart of Copenhagen that was advertised on Airbnb as in the 'Brooklyn-style'. He could've chosen somewhere else, but as he told me recently in an episode called *Gentrification* for BBC Radio 4's *Digital Human*, he didn't. And he thought it was ridiculous that he could stay in a Brooklyn-style

apartment in Shanghai or Stockholm, and drink coffee in cafes that looked the same – complete with cookie-cutter tattooed baristas – but he did it. Maybe you do it too.

While shifts in design are millennia old, Kyle argues that trends are now being distributed globally in epic ways, thanks to the importance we place on posting and sharing our surroundings on apps like Facebook, Pinterest, Foursquare and Instagram. The apps' algorithms dictate what we see, and so we all end up liking, desiring and sharing the same things. Uniqueness isn't rewarded in AirSpace, except within parameters – and often these are economically and culturally biased. While all this homogeneity is not great if you're looking for traditional tea pagodas in Tokyo, it's comforting for those who spend much of their time on the road and just want fast internet, strong coffee and other luxuries of home.

But no algorithm could've predicted that I'd make a programme about AirSpace, nine years after I first visited it... **SF**



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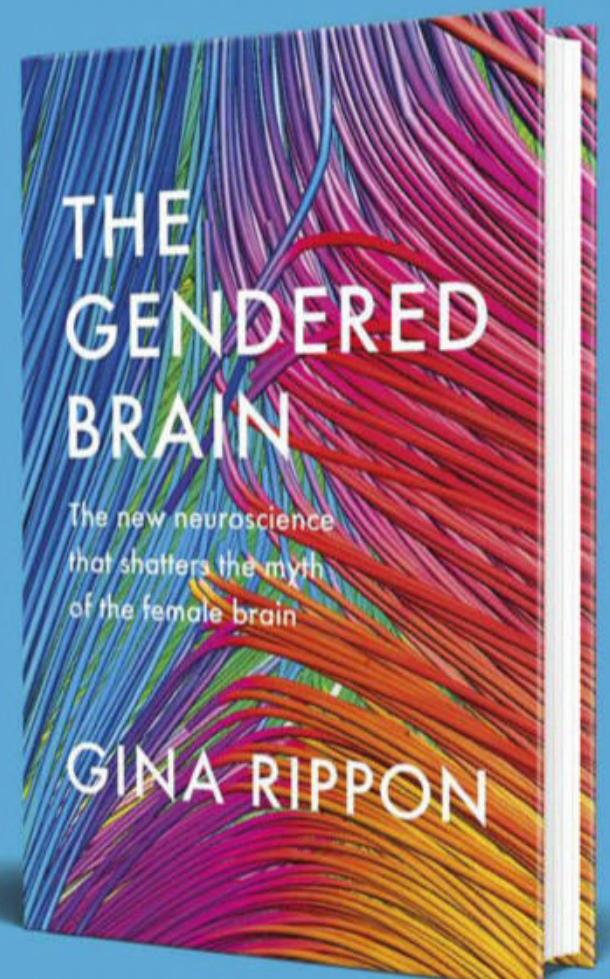


MALE AND FEMALE BRAINS: A SEXIST MYTH OR A FACT OF LIFE?

'SMART AND WITTY... Gina Rippon is one of the most outspoken scientists in this area, and she debunks a whole host of sexist stereotypes'

ANGELA SAINI, author of *Inferior*

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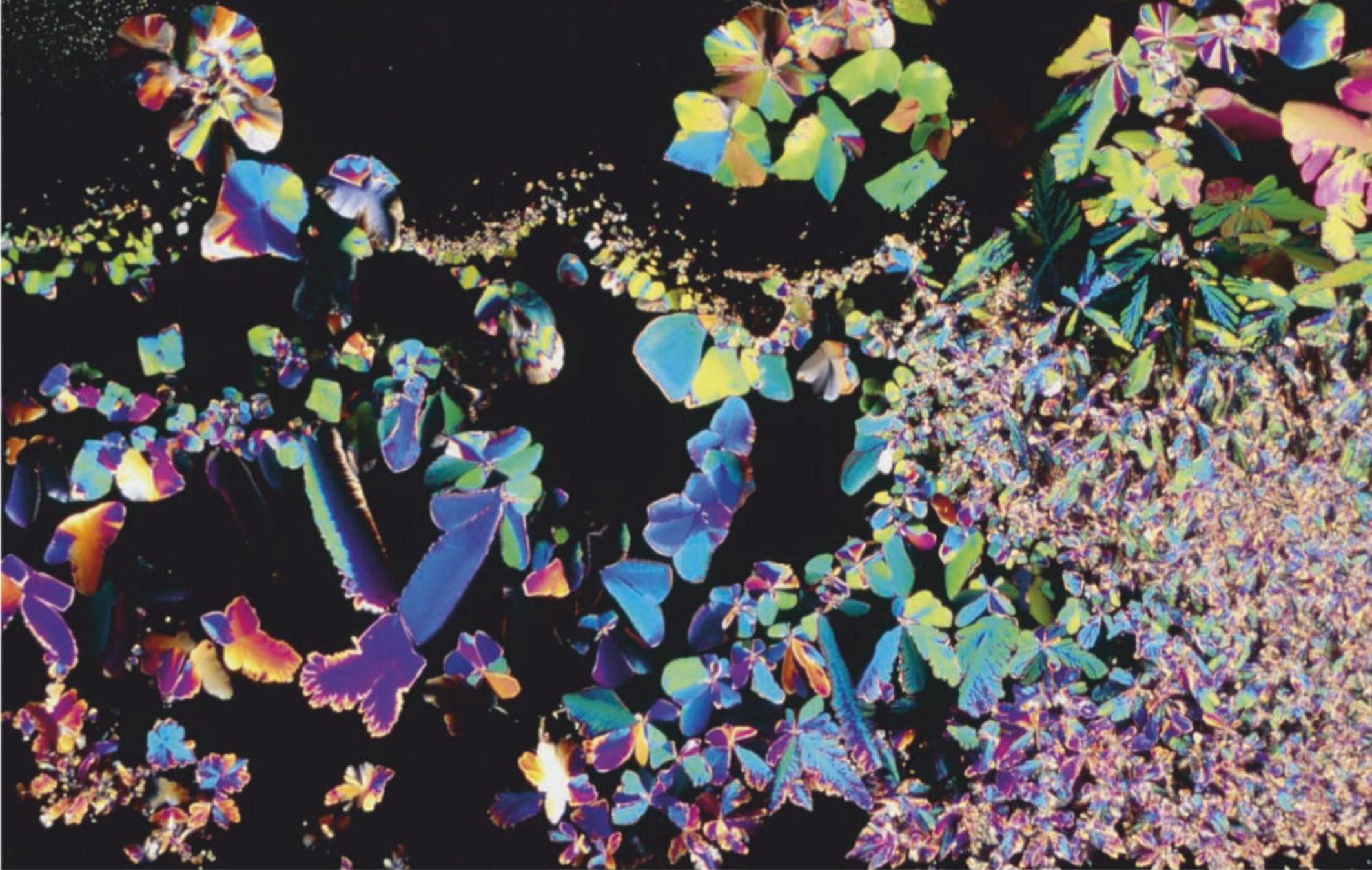


THE HIDDEN POWER OF YOUR BRAIN

by ANDY RIDGWAY (@andyridgway1)

New research is discovering that the way you think about life can fend off infection, help you live longer and even spare you from the surgeon's knife...

ILLUSTRATION: EIKO OJALA



"PEOPLE WITH HIGHER LEVELS OF POSITIVE EMOTIONS DO A BETTER JOB OF MANAGING STRESS"

Nobody likes catching a cold. But it seems that we all have a pretty effective weapon that can reduce our chances of getting one – being happy. In a study published back in 2003, over 300 volunteers in the US were knowingly infected with a virus responsible for the common cold. They were then monitored for symptoms over the next five days. The results were clear. Those with the most positive outlooks on life were three times less likely to develop cold symptoms than those who were the least happy. Other studies have reached similar conclusions.

A positive mental attitude can have long-term health benefits too. In the US, the autobiographies of 180 Catholic nuns in their 20s and 30s were analysed by psychologists to see what they revealed about their personalities. It showed that those who were positive and happy tended to live 7 to 10 years longer than those who weren't.

In spite of such studies, the influence of our mind over our health has left some

members of the medical community decidedly sceptical. But there's a growing body of research showing that what goes on in our heads has a direct influence over how healthy we are. Not only that, our thoughts can even help cure us of some ailments. Importantly, researchers are now starting to understand more about the mechanisms at work – how our thoughts are connected to our physical health.

STAY POSITIVE

A researcher at the forefront of this field is Dr Laura Kubzansky, co-director of the Center for Health and Happiness at Harvard School of Public Health. One of her most recent studies – so recent, in fact, that it has not yet been published – involves just over 70,000 nurses in the

LEFT The hormone cortisol, seen here in a microscope image taken with polarised light, is released in response to stress. High levels over long periods of time have a negative effect on health

US. In the research, she discovered that those who are the most optimistic have roughly 15 per cent longer lifespans than those who are the least optimistic.

In part, it is thought that differences in longevity like this are down to the fact that those with positive attitudes tend to do more exercise and smoke less. But it is not just that. "People with higher levels of positive emotions do a better job of managing stress," explains Kubzansky. "So a lot of the stress-activated biochemical processes, like higher levels of cortisol that are circulating and driving inflammation, are less likely to occur." Reduced stress also reduces 'allostatic load' – a medical term for the general wear and tear on the body, such as strain on the internal organs, that takes place under long-term stress.

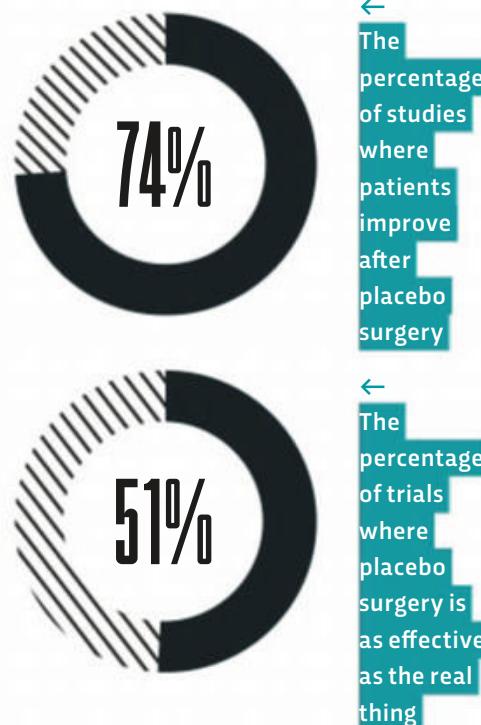
But, says Kubzansky, this is likely to just be part of the picture – there will be other biochemical processes within our cells that are influenced by our positivity that we're not aware of yet. Part of the problem is that medical research has been understandably focused on getting to grips with what's going on in our bodies when we're ill, rather than when we're feeling well and things are going right. "We're not very good at looking at the biology of good functioning, we mostly just look at the biology of normal or bad," she says. "But the time for positive biology has come."

One of Kubzansky's priorities now is to look at how our microbiome – the bacteria and other microorganisms that live inside our bodies, particularly in the gut – are influenced by how positive we are. "There is some preliminary research that links depression to alterations in the gut microbiome, so it's logical to speculate that you might get effects in the other direction," says Kubzansky. The effect of our mental state on the microbes inside us is a big deal because the health and make-up of these microbes has been linked to several aspects of our physical health, such as whether or not we're overweight.

TRICKING THE TELOMERES

There's already evidence that the way we think can influence our DNA. For more than a decade now, the laboratory of molecular biologist Dr Elizabeth Blackburn at University of California, San Francisco, has been investigating the influence of our state of mind on our telomeres – the chunks of DNA that act as protective caps at the end of chromosomes. Telomeres get shorter each time a cell divides and if they get too short, the cells in which they are located no longer divide and so they die. Short telomeres have been associated with everything from heart disease to lung conditions. Blackburn was awarded the Nobel Prize in 2009 for her research on telomeres and telomerase, which is an enzyme that fights against the tendency of

THE ETHICS OF PLACEBO SURGERY



The mind has a big role to play in how effective surgery is. One influential study, published in the prestigious *British Medical Journal* (BMJ), pulled together the results of more than 50 surgical trials that compared a widely used surgical technique, such cleaning out painful knee joints with salt water, with a placebo surgery. It showed that in 74 per cent of the studies, patients who just had the placebo surgery showed signs of improvement, such as reductions in pain. In fact, in 51 per cent of the trials, placebo surgery was as effective as the real thing.

There are few who would doubt the importance of using placebo surgery to test out existing surgical techniques. But given that placebo surgeries do seem to work, isn't there an argument for using them as a treatment in their own right? "Fake surgery is not benign, it's not a sugar pill," says Dr Ted Kaptchuk, a leading placebo researcher at Harvard Medical School. "It has real costs and dangers." It means placebo surgery can't be justified ethically, he says. However 'open-label placebo' medication, where patients are told that their treatment – whether it's a pill, medicine or cream – doesn't contain an active ingredient is justifiable, he says. The other ethical approach to harnessing the power of the brain, says Kaptchuk, is to use 'conditioning'. Here the body is tricked by pairing a known treatment, such as the painkiller morphine, with something that has no effect, like saline solution. If the two are injected together, eventually when the saline is injected on its own, it acts like a painkiller.

• telomeres to get shorter and shorter over time.

Blackburn's lab first looked at the telomeres of mothers who were caring for children with long-term health conditions. They found that the longer the mother had been looking after the child – so under stress – the shorter her telomeres. "It was very striking," says Blackburn. After that, they investigated other potential influences of the mind on DNA. It turns out that, on average, pessimists have shorter telomeres

"THE PLACEBO EFFECT HAS BEEN RECOGNISED FOR CENTURIES – AT WORST IT'S BEEN VIEWED AS A VILLAIN OR A THREAT TO MEDICINE"

says Blackburn. The good news is that we can boost our telomerase levels. In one study Blackburn was involved with, 30 volunteers spent three months at a retreat in Colorado meditating for six hours a day. By the end, levels of telomerase in their cells were one-third higher compared to another group who did not go on the retreat. It is thought that the telomerase boost wasn't specifically down to meditation – it was more due to the increased sense of wellbeing the volunteers had. So anything that increases the sense of wellbeing is likely to have the same effect.

PLACEBO EFFECT

When it comes to the influence of our minds on our bodies when we're ill, the most widely known phenomenon is the placebo effect. Here, when someone takes medication that has no active ingredient, such as a sugar pill, it can do anything from numbing headaches to relieving symptoms of colds. It all comes down to *believing* the medication will help. Examples of placebo treatments have been documented for centuries, but more recent research has provided some intriguing insights. For example, in one study in Italy, a placebo tranquiliser was better at soothing patients' nerves before an operation if it was blue – or at least that was the case with female patients. Orange pills were most effective with the men.

The placebo effect plays a role when we have surgery too. Some common surgical techniques have been tested against 'placebo surgery', where a patient thinks they are having full-blown surgery but in fact they may just have an incision in their skin, or some other minor procedure. In many studies, the placebo surgery has been just as effective as the real thing. Research such as this is typically used to question whether certain surgical procedures should take place at all. But some scientists say that we've been thinking about the placebo effect in completely the wrong way. It's not something to just test a surgical technique or a drug against, we should actually start to use it to treat patients.



than optimists. And being cynical isn't good for your long-term health either. In one study on more than 400 British civil servants, they found that those who showed higher levels of 'cynical hostility' towards others – so were more likely to answer 'yes' to the question 'most people make friends because friends are likely to be useful to them' – had shorter telomeres.

But how can the way we think affect our DNA? For starters, when we're stressed over long periods of time, levels of the hormone cortisol go up. "We know that higher cortisol dampens down the replenishing action of telomerase,"

ABOVE Protective telomeres (yellow) can be seen on the ends of this chromosome (blue)

GETTY IMAGES X2



Nobel
Prize-
winner Dr
Elizabeth
Blackburn
researches
telomeres
and how
they affect
ageing

"The placebo effect has been recognised for centuries – at worst it's been viewed as a villain or a threat to medicine, such as when a new drug that developers have spent billions [developing] gets beaten by a 'mere placebo,'" says Dr Alia Crum, principal investigator at Stanford University's Mind and Body Lab. "But there is huge potential for it to be used for good."

It's a point Crum makes in a TED talk about the placebo effect (see *Discover More*, p94). She describes one of her experiments that showed a placebo cream with no active ingredients could be used to clear up allergic rashes, but only when the doctor was warm and friendly and showed signs that they were good at their job, such as wearing a badge saying 'Fellow at the Stanford Allergy Center'. "Our research shows that the placebo effect is alive and at play in every single medical encounter," she tells *Science Focus*. According to Crum, we just need to train doctors to think about what they do and say in front of patients to harness the placebo effect more effectively.

In most placebo studies, each volunteer is told they will either receive the real treatment, or a placebo. But Dr Ted Kaptchuk, a placebo researcher at Harvard Medical School, decided to actually tell volunteers he was going to give them a placebo pill for irritable bowel syndrome. "Every placebo researcher in the world said 'Ted, you are crazy,'" he says. But bizarrely, it still worked. The patients said their symptoms improved by 60 per cent. "In fact, it's consistently worked in nine studies," says Kaptchuk.

It undermines one of the common explanations of why a placebo works – that patients think they are getting the real treatment and so it works because they *expect* it to. Kaptchuk says that many of the patients who come to him for trials of these 'open-label placebos' have tried many other treatments for their condition that haven't worked, ➤

CAN WE MEASURE HAPPINESS?

If being happy is good for your health, helping you to fight off a cold and even prolonging your life, what is happiness? We know when we *feel* happy but can we actually detect happiness inside us?

Dr Mark Holder, an associate professor of psychology at the University of British Columbia in Canada, decided to find out. "I had conceptualised happiness as the opposite of depression; so if you think of a continuum, the more you move away from depression, the happier you are." So he asked some of his students to provide him with spit and urine samples and he measured levels of two hormones – cortisol and

serotonin. After all, antidepressant drugs are designed to increase serotonin levels, and high levels of cortisol have also been linked to depression. The trouble was, neither cortisol nor serotonin levels in the students' samples showed any relationship with how happy they were. "It tells me that my conceptualisation of happiness was wrong," says Holder. In other words, happiness

and depression can't be thought of as opposites of the same spectrum. He didn't give up, though. "We looked at some putative biomarkers," he says. "That's a fancy way of saying, 'I took some guesses!'" He next measured neural growth factors – proteins that control the growth of nerve cells. Again, he drew a blank. "We haven't been able to unravel the biochemistry of happiness," says Holder.



● and their hope and uncertainty seem to play a role. Kaptchuk also says placebos tend to be most successful with conditions that have a big psychosocial component, where mental factors and perceptions are involved, such as chronic pain. "Open-label placebo doesn't get rid of malaria, doesn't lower cholesterol," he says.

While we still don't quite understand the psychology driving the placebo effect, there's no doubt that it has an influence on the body. In research on placebo painkillers, for example, when neurotransmitters such as endorphins and dopamine are blocked, the placebo effect is stopped.

POWER OF THE MIND

The healing power of the mind doesn't stop at the placebo effect. In

"THIS RESEARCH POINTS TO A FUTURE WHERE OUR MINDS PLAY MORE OF A ROLE IN OUR HEALTH"

his famous experiment, Russian physiologist Ivan Pavlov conditioned dogs to salivate when they heard a sound, such as the ticking of a metronome, if they first heard that sound several times when being fed. Similar 'training' could be used on patients too.

Studies have shown that when a medical treatment is paired with something else, such as a sweet or a smell, that something else can produce the same effect as the medicine after a while. In one study in Germany, for example, this

technique enabled volunteers' bodies to produce natural killer cells – cells that are part of the immune system – in response to a sherbet sweet. The idea is that in the future, the bodies of patients could be trained to subdue pain, fight infections or calm allergies by conditioning. Eventually, long-term medication may not be needed.

All of this research points towards a future where our minds play more of a role in our health, both when we're well and when we're sick. But there's a million dollar question – how much can we actually change our mindset anyway? "It's not easily modifiable," says Kubzansky. "I don't think somebody one day says, 'I'm going to be more optimistic today'. If it was that easy we'd all be in utopia. But I do think it's modifiable with some focused attention." When it comes to harnessing the power of the mind in medical treatments, it seems there's still work to be done to change the mindsets of some in the medical community. "The question is, how do you move the system?" says Kaptchuk. "Sometimes it's science, sometimes it's will, sometimes it's the imagination." SF

—
by ANDY RIDGWAY (@andyridgway)
Andy is a freelance science writer and science communication lecturer based in Bristol.

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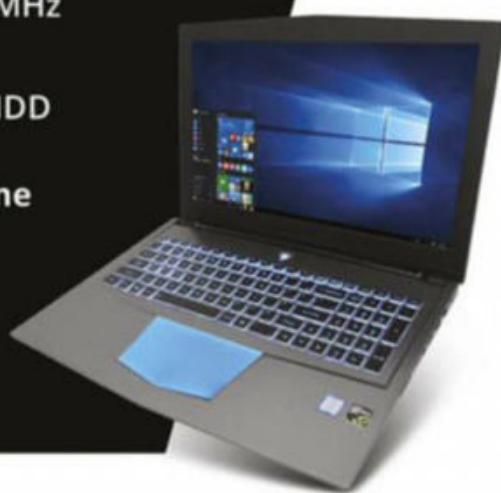
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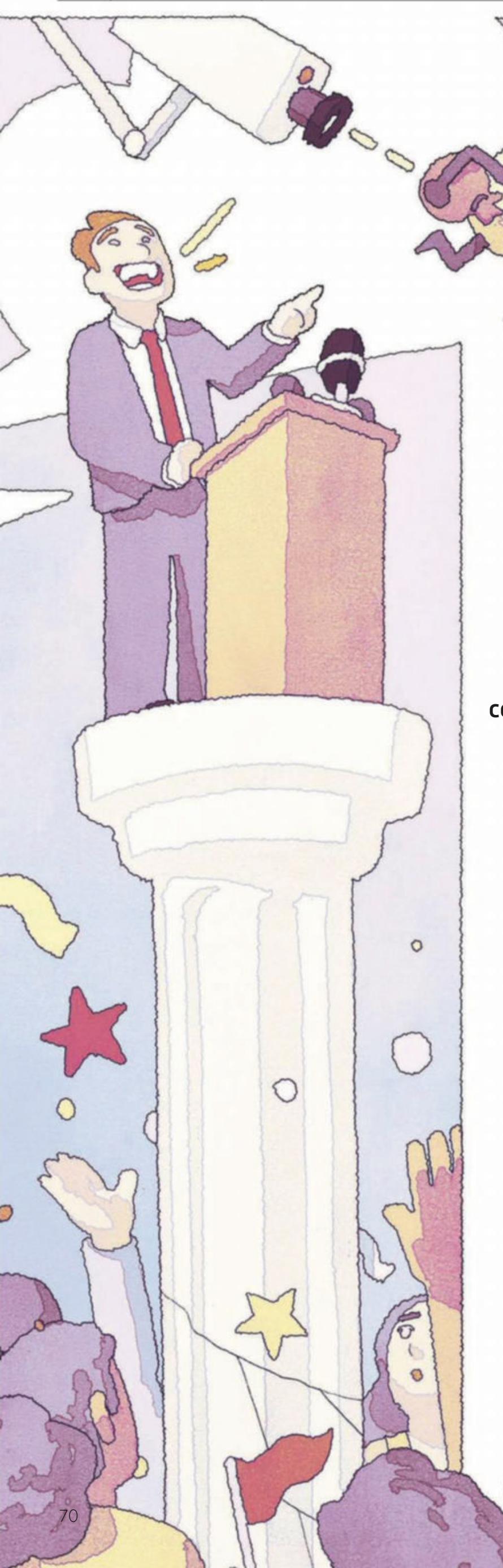
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HOW CHARISMATIC LEADERS FAIL UPWARDS

Words Helen Glenny

Illustration Kyle Smart

Despite blunder-filled careers, confident officials often rise above more capable colleagues. Why? And why is it happening now?

B

ack in 1995, McArthur Wheeler robbed a Pittsburg bank in broad daylight, armed with a gun. Bolstered by the success of his first attempt, Wheeler robbed another. Despite both banks being wired with security cameras, it seemed that Wheeler had made no effort to disguise himself, so police played the surveillance tapes on the 11 o'clock news. Perhaps unsurprisingly to everyone but Wheeler, an informant recognised him and he was arrested later that night. When police showed him the footage, he was stunned. "But I wore the juice," he mumbled.

Lemon juice can be used as an invisible ink that reveals a message when heated (the sugars in the juice turn brown). Wheeler had learned this and arrived at the conclusion that a squeeze of lemon on his face would render it invisible to the bank's cameras, just as long as he didn't get too close to any heat sources.



As surprising as Wheeler's error of judgment was, his overconfidence might sound familiar if you've been following politics lately. High-ranking figures seem to consistently underestimate the difficulty of the task in front of them, such as the UK's former Brexit Secretary, Dominic Raab, who stated he "hadn't quite understood" how reliant UK trade is on the English Channel's Dover-Calais crossing (2.5 million heavy goods vehicles cross every year). In the US, Donald Trump's travel ban, initiated in 2017, caught border officials by surprise, leading to mass confusion about who to let in. It was a big move, spearheaded by a president underestimating the complexity of his aspirations.

On both sides of the Atlantic, and of the political spectrum, it's become all too common to see the ascent of supremely confident leaders, who brush off mistakes with a charismatic smile. Whether they're from the world of politics or business, these figures appear bulletproof, bouncing from one influential role to the next. So what can the study of leadership psychology tell us about what's happening, and why is it happening now?

THE INCOMPETENCE DOUBLE-BURDEN

Inspired by Wheeler's optimistic armed robberies, social psychologists David Dunning and Justin Kruger designed an experiment. They tested university students' logical thinking skills, knowledge of English grammar and sense of humour, and then asked the students how well, or badly, they think they did. All three tests supported their hunch: the students who performed among the worst had no idea how bad they truly were. "On average they were only outperforming 10 to 15 per cent of the people in our sample, but they thought they were outperforming 60 per cent. They were almost as confident as the people at the top," says Dunning. This phenomenon is now known as the

Dunning-Kruger effect. It describes how the incompetent suffer a dual burden; not only are they bad at the task at hand, they're so bad that they're blind to their own ineptitude. As a result they enjoy an inflated sense of their own abilities and tackle tasks in a blissful state of overconfidence. Two decades on, the Dunning-Kruger effect is being noted in worrying new areas.

A 2018 study across several American universities reported that extreme opponents of genetically modified foods know the least about science and genetics, while believing they know the most. Another study published last year surveyed 1,310 US adults about the causes of autism and whether or not it is linked to vaccinations. "A third of Americans say they know as much as doctors and experts," says Dunning, who wasn't involved in the study. "But that third is actually the most misinformed."

Dunning himself sees the effect often among people in positions of authority, recalling the case of the Crystal River power plant in Florida. The company running the plant tried to cut costs by managing a complicated repair job themselves, which ended up creating more damage to the concrete shell of the building that kept the radiation from escaping. One source put the estimated cost of the mistake at \$3bn (£2.3bn approx). "You can see it in a lot of places in life," Dunning says. "Unfortunately, you often see it after the fact."

CONFIDENCE IMPLIES COMPETENCE

In politics, it's well documented that we gravitate towards confident, charismatic leaders. "People take confidence as a prime indicator of competence," says Dunning. "You see that in the courtroom with which witnesses to follow. You see it in the office, in terms of which bosses to follow."

Psychologists studying influence often talk about competence cues. These are signs that the person in front of us ➤



• knows what they're talking about, such as speaking opinions loudly and without hesitation. We read body language and use it to assume competence, too, such as using emphatic gestures when making points and appearing at ease with tasks. Former prime ministers David Cameron and Tony Blair were both famous for their confident hand gestures. And numerous politicians, from both ends of the political spectrum, have been photographed in the "power stance": upright with their legs spread exaggeratedly far apart. Body language experts have speculated that they've been advised to take up as much space as possible, another competence cue.

What makes confidence so appealing? Dr Sander van der Linden, a social psychologist at the University of Cambridge, describes the typical charismatic leader as someone who articulates an ideological vision, and tends to talk about distant goals more than near-term goals because they don't have anything concrete to offer. "They have very clear and simple ideas about how they're going to overcome massive social problems with this grandiose vision," he says. This fits across the Atlantic, too – Trump's 'Make America Great Again' is a fine example of a grandiose but vague proposition.

In van der Linden's lab, he studies how groups of people behave when faced with tricky tasks that require cooperation. "If I put some students together in a room and ask them to sort themselves out, what tends to happen is that students drift towards the person who's confident, slightly aggressive and has a vision of what they're supposed to be doing and how to implement it," he says. "Because that resolves a lot of cognitive complexity for people. Imagine you don't really know what the task is, and somebody shows confidence

and ability and they communicate in a simple way, and they seem to have everything figured out. It's much easier to follow that person." The allure of confidence is understandable, and familiar, particularly when it comes to complex, messy problems. You can imagine being tempted to hand control over to the UK's international trade secretary Liam Fox, given his confidence that "The free trade agreement that we will have to come to with the European Union should be one of the easiest in human history."

MISATTRIBUTION OF MISTAKES

Unfortunately it seems that once a person has created a confident image of themselves, it's a hard perception to shift. In reality, according to van der Linden, when you're a confident leader you're less likely to cop the blame when something goes wrong. In 2004, researchers tested participants' perceptions of President George W Bush, and discovered that those who found Bush charismatic were less likely to blame him for failures in the Iraq war. The researchers then created a "crisis condition" in which participants were alerted to a warning from the CIA that al-Qaeda was planning a terrorist attack in the US. When encouraged to worry about terrorism, participants found Bush more charismatic and were even less likely to attribute blame to him. It's a potent combination; a charismatic leader that makes us feel like we're in safe hands, operating in a time of crisis.

Social and political crises can make us feel distressed, anxious and hopeless, so it's understandable that in those situations we are drawn to leaders who promise to deliver better times. Academics have recognised that Brexit is causing some UK citizens anxiety,

creating what van der Linden calls a “charisma-conducive environment” in which we’re much more susceptible to charismatic leaders offering simple solutions. In one slightly morbid experiment, published in *Psychological Science* in 2004, researchers asked participants to write down what they felt when they imagined their own death, and what they think will happen to them physically as they die. With thoughts of their own mortality front and centre, 33 per cent of participants favoured a charismatic candidate in a hypothetical election, compared with just 4 per cent in a group who had not been primed to consider their own death. In another experiment, participants were reminded of recent terrorist attacks and read an argument that similar attacks could take place locally. Those people were more likely to favour a charismatic leader, even when that leader was presenting political messages that conflicted with the participants’ own values.

van der Linden points to Germany in the 1930s as a clear example of citizens being susceptible to a charismatic leader in troubled times. “Leading up to WWII, where people were suffering, Hitler emerges as a grand leader with a new vision. Charismatic leadership, especially when it comes to advancing ideas that people otherwise wouldn’t readily accept, is more likely to occur when there’s fear, uncertainty and social unrest, which confirms what we see in experiments.”

AVOIDING THE PITFALLS

It’s clear that making good collective decisions around who to elect isn’t getting any easier. The issues that matter, like climate change, healthcare provision, economic policy and unemployment have no simple solutions. That may



have left people craving apparently strong leaders; ones that seem to have all the answers. So how can we instead ensure we pick capable leaders? According to van der Linden, we shouldn’t ignore charisma altogether – just look for leaders with the right motivations. “Personally-driven, charismatic leaders [seek positions of power] because it offers control and influence. But we also have charismatic leaders that are collectively-oriented and egalitarian, who care about their followers and have the best for them in mind.”

Dunning says an antidote to the effect that he and his colleagues first described is to seek out the opinions of neutral experts: with expertise comes the ability to accurately judge the capabilities of those around you, even when expertise and intellectualism is attacked.

Dunning also notes that confidence has its place. “There are situations in which even unrealistic confidence is good, and situations in which unrealistic confidence is very, very bad,” he says. “In the preparation stage of things, you really want to be underconfident or obsessive. But on the day of battle you can’t really show doubt. It’s time to lead. You need to know where confidence works, and where it works against you.” SF

by HELEN GLENNY (@hcglennny)

Helen is the editorial assistant at BBC Science Focus.



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DR PAUL BARKER, BOURNEMOUTH

WHEN I LOOK TO THE STARS, HOW FAR BACK AM I SEEING?

All of the stars you can see with the unaided eye lie within about 4,000 light-years of us. So, at most, you are seeing stars as they appeared 4,000 years ago. All of these stars will die at some point, and astronomers have estimated that the death rate for visible stars in our Milky Way is around one star every 10,000 years. So given that we can only see 4,000 years back in time, it is unlikely (though not impossible) that any of them have died yet. In other words, choose any star in the night sky, and the chances are that you could visit it today (if you had a fast enough spaceship). *AGu*



ASH CLASS, BOSMERE PRIMARY SCHOOL, IPSWICH

SHOULD CHILDREN USE MOUTHWASH?

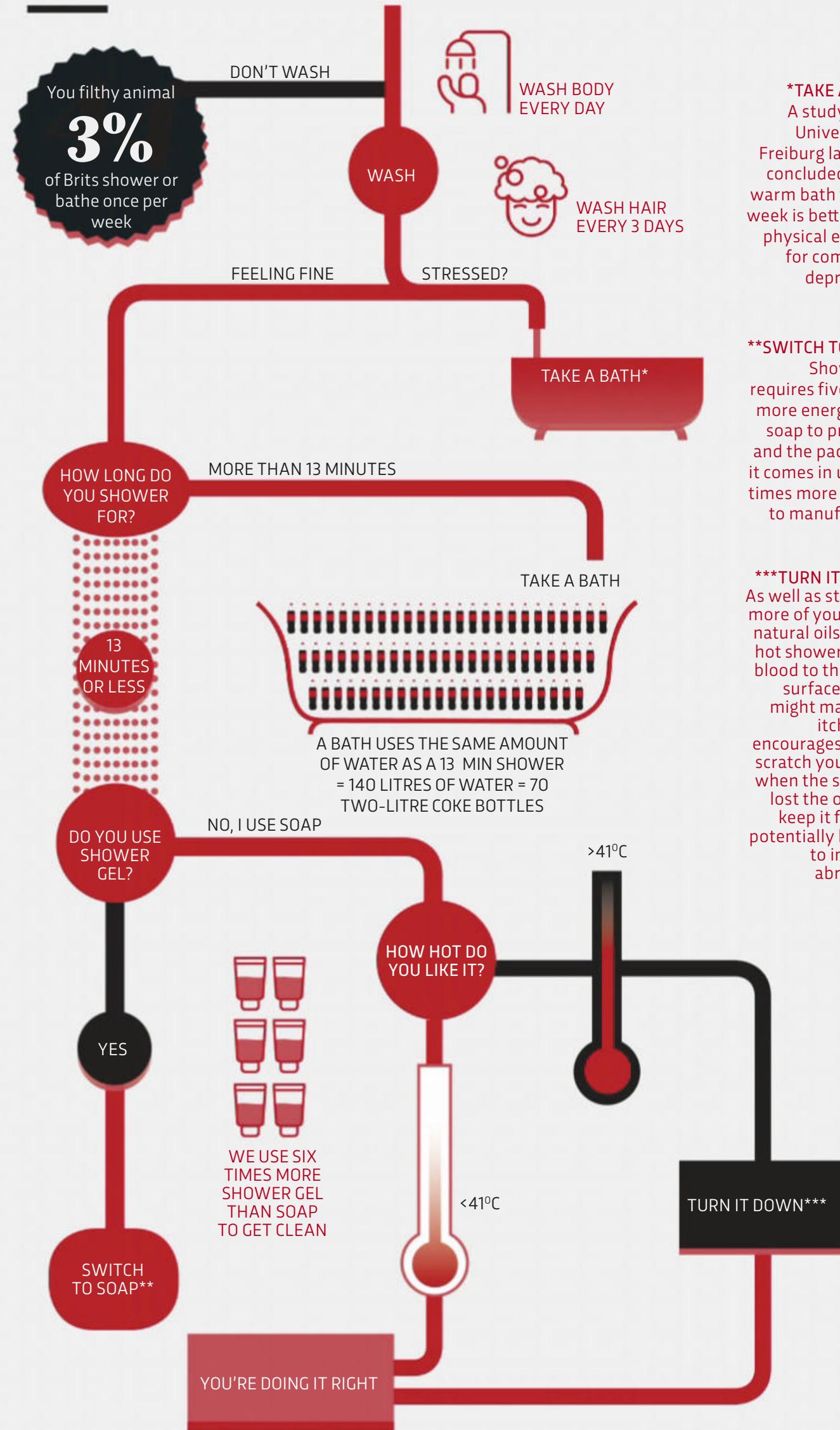
Research on children aged 6 to 14 has found a large reduction in tooth decay when using a fluoride-based mouthwash. However, all the trials gave the mouthwash to children in a supervised setting at school, in between teeth brushings. There's no evidence that a quick rinse at the same time as you brush your teeth provides any extra benefit. So a rinse during lunchtime could be beneficial, but children are recommended to check with their dentist before using mouthwash. **LV**

JACK STECHER, DALLAS, TEXAS

WHY DOES LIGHT LEAVE THE POSITION FROM WHICH IT IS CREATED?

Light is a manifestation of the laws of electromagnetism, which show that whenever sources of electric charge – such as electrons – are accelerated, the resulting energy is converted into waves of electromagnetic energy that travel outward from the source at the speed of light. In other words, it's impossible for light to stand still – the laws of physics decree that it's always on the move. **RM**

ALGORITHM YOUR LIFE: HOW SHOULD I KEEP MYSELF CLEAN?





OTTO MAYO (11 YEARS OLD)

WHAT ARE THE WIGGLY THINGS I SEE IN MY EYES WHEN I LOOK AT THE SKY?

When looking up at a blue sky, many people see tiny dots in their field of vision that follow squiggly lines. These move in sync with our pulse, briefly accelerating with every heartbeat, and they usually disappear after about a second.

The dots are actually white blood cells moving along the fine blood vessels (capillaries) in front of the retina at the back of the eye. This experience is called the 'blue field entoptic phenomenon' because it's especially noticeable when looking into bright blue light, such as a cloudless sky. Whereas red blood cells absorb blue light, white blood cells do not, so they let the light through to the retina. Light-sensitive cells in the retina read this as a signal of increased brightness, causing us to see the white blood cells as spots. **ED**

30 cm

The length that the empress tree (*Paulownia tomentosa*) is capable of growing in three weeks

EXISTENTIAL FEAR OF THE MONTH...

...THERE'S POO EVERYWHERE

It's true. Last year, London Metropolitan University conducted swab tests on the self-order touchscreens in eight McDonald's restaurants and found faecal bacteria on all of them. This isn't because these restaurants are dirty: it's because their customers are, and so are you. Every one of us has about 0.1 grams of poop trapped in our butt crack at any given time. This spreads to our clothes, then our hands and then to every surface we touch.

You can clean the bathroom as much as you want, but bacteria are distributed as a fine mist every time you flush the toilet and will hang in the air for up to two hours, waiting to land on the next person

to walk in. And your kitchen sponge, which you use to *clean* the dishes, has twice as many bacteria per square centimetre as your bathroom. In fact, every door handle, TV remote, keyboard, lift button, bus handrail and car seat has detectable amounts of either your poo, or someone else's. Of course, poo has always been everywhere: we just didn't have the tools to detect it until the 20th Century. And it's nothing to worry about. If your immune system is working properly, the low levels of contamination present today aren't enough to make you sick. But washing your hands before you eat in a public place is always a good idea. **LV**



GRAHAM POLLARD, SADDLEWORTH

WHAT ARE GRAVITONS, AND DO THEY REALLY EXIST?

Gravitons are at the heart of arguably the biggest challenge in theoretical physics: the search for the 'theory of everything' – a set of equations describing all of the forces and particles in the Universe. For decades, theorists have struggled to unify Einstein's theory of gravity, known as General Relativity (GR), with quantum theory, which describes the subatomic world. That's because each theory takes a radically different view of the force of gravity. According to Einstein, matter distorts the very fabric of space and time around it, creating the effect of an attractive force field. But quantum theory describes all forces in terms of so-called 'exchange particles', flitting from place to place. In the case of gravity, those particles are



known as 'gravitons'.

Most theorists believe that gravitons must exist, because quantum theory has successfully explained every other force of nature. But not everyone agrees. No theory claiming to unify quantum theory with GR has been successfully verified, and this has raised suspicions that perhaps gravity isn't like any other force – in which case gravitons may not exist.

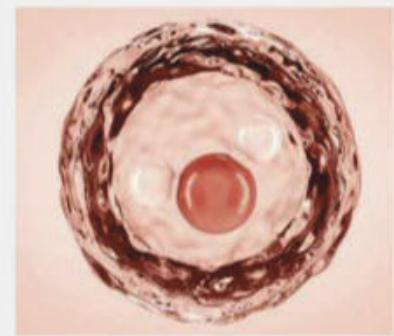
Even if they do, finding them is another matter. Quantum theory predicts that as gravity has an effectively infinite range, the

graviton must have an incredibly low mass. Studies of gravitational waves from colliding black holes suggest that the graviton must be at least a billion, billion, billion times lighter even than the electron.

Gravity is also by far the most feeble fundamental force in nature. This means that any graviton detector must be incredibly massive and placed near a powerful source of gravitons. Calculations suggest that even a detector with the mass of Jupiter orbiting a bizarre object like a neutron star (a potential strong source of gravitons) would struggle to find anything. **RM**

ARTHUR NEWBY, LIVERPOOL

HOW DO TWO GASES COMBINE TO MAKE LIQUID WATER?



Hydrogen and oxygen atoms are attracted to one another by the electrostatic force between their positively charged protons and negatively charged electrons. This chemical bond isn't very strong – but it's enough to overcome the random motion that the atoms undergo at temperatures between 0°C and 100°C that would otherwise keep them as separate gases. As a result, pairs of hydrogen atoms team up with individual oxygen atoms in a relatively dense but loose arrangement of H₂O molecules we call liquid water. **RM**

MARINA TAYLOR, LONDON

WHY DO SOME PEOPLE HAVE SUCH A POOR SENSE OF DIRECTION?

Knowing which way is which depends on compass-like processes in the frontal and temporal lobes of the brain. A recent study found that relevant structures in these areas were larger in people with a better sense of direction (based on lab tests), suggesting a neurological basis for why some of us are more aware of direction than others. Other research has found that women, on average, require more cues in the environment to know which way they are facing. There are also links with personality – extraverts, open-minded people and the more conscientious all tend to have a better sense of direction. Another consistent finding is that people have good insight into their directional abilities, so whether you believe you're a walking compass or feel like you're forever in a spin, it's probably true. **CJ**



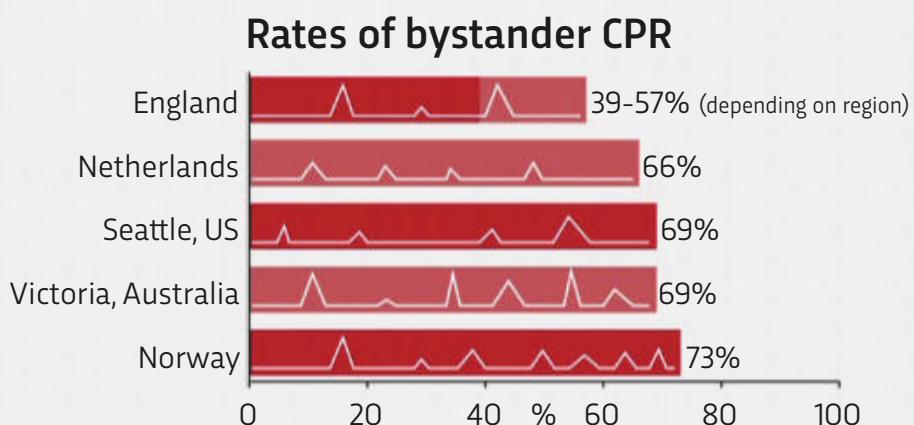
DAN JONES, LONDON

SHOULD YOU GIVE THE KISS OF LIFE TO SOMEONE HAVING A HEART ATTACK?



When faced with someone who's collapsed and not breathing, the best medical advice is to first call 999 and then perform CPR – cardiopulmonary resuscitation. This involves locking your fingers together and pushing down hard and fast on the casualty's chest until paramedics arrive. But there's controversy about combining this with mouth-to-mouth resuscitation – the 'kiss of life', also known as 'rescue breaths'. Multiple studies suggest that the added benefits aren't

worth the pause in the chest compressions, and the prospect of using it on complete strangers is thought to deter many people from doing anything at all. Nevertheless, the British Heart Foundation and the NHS both still recommend using mouth-to-mouth where possible, suggesting an alternative 'hands-only' CPR for those who don't feel comfortable giving rescue breaths or who haven't been trained. **RM**



NATURE'S WEIRDEST CREATURES...

THE AYE-AYE

Lemurs exist only on the island of Madagascar. Most of these primates are furry, cuddly-looking creatures, except one: the aye-aye.

The aye-aye possesses rodent-like teeth that never stop growing, piercing eyes that allow it to forage at night and a middle finger so long and bony that it almost looks like a spider's leg. Incredibly, the aye-aye has woodpeckers to thank for this latter adaptation. Woodpeckers never made it to Madagascar, which meant the aye-aye could fill the niche for eating wood-boring grubs. The animal taps its elongated middle finger against tree stumps to locate grubs, listening for the telltale echoes of hollow areas, which indicate the presence of food.

This hunting technique makes the aye-aye the only known primate to echolocate its prey: hence its extraordinarily sensitive, bat-like ears.

The aye-aye is to lemurs what Stephen King's Pennywise is to clowns, at least according to local Malagasy legend. One belief is that this creature creeps into the houses of villagers at night and uses its elongated finger to slit the throats of sleeping children. The truth – if you're a grub – is just as grisly. **JH**



QUESTION OF THE MONTH

FREDDIE SENIOR,
SUNNINGDALE SCHOOL

IF WE HAD 2019'S TECHNOLOGY 2,000 YEARS AGO, WHAT WOULD TECHNOLOGY BE LIKE TODAY?

Two-thousand years ago, the human population was about 300 million – 4 per cent of today's. With 2019 satellite imaging and computer modelling, you'd hope our ancestors would have been able to see that fossil fuels and rising human populations would destroy our climate and cause mass extinctions of life on Earth. So today we would probably have completely clean tech:

all of our vehicles would be electric, and all power sources renewable. We would live in places designed to harm our planet the least: enclosed cities built among mountains, deserts or under oceans. Computers would likely play an even bigger role in our lives, with invisible data processing integrated into every artefact, from clothing to walls. Our technology would

help us to stay healthy, removing almost all disease by artificially boosting our immune system, while brain-computer interfaces would enable us to communicate with our devices through thought alone. Meanwhile, intercity transport would take place via underground, vacuum-tube trains, travelling at 8,000km/h. **PB**



WINNER

Freddie wins a bunch of science books by Brian Clegg: *What Colour Is The Sun?*, *How Many Moons Does The Earth Have?*, *Gravitational Waves* and *Big Data*. We're also throwing in copies of *Destination Mars* and *Cosmic Impact*, both by Andrew May. iconbooks.com



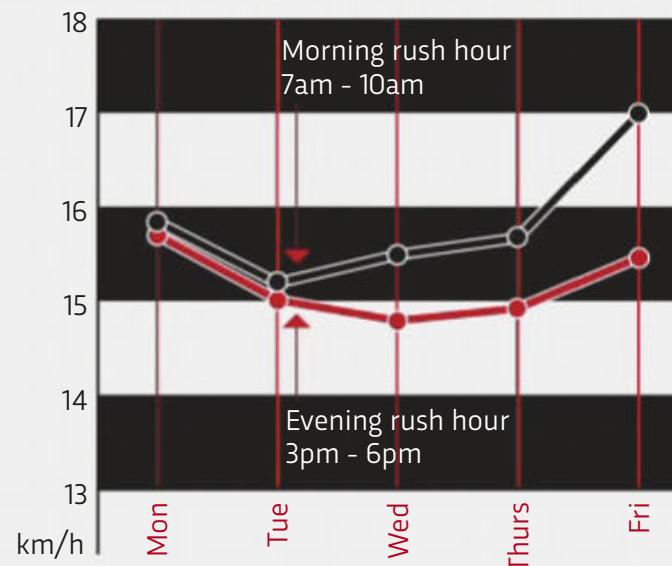
REBECCA RIDLEY, MANCHESTER

WHY IS TRAFFIC ON MY COMMUTE BETTER ON FRIDAY MORNINGS?

Many people think it's easier to drive into work on Friday morning, the theory being that lots of people end their working week on Thursday so that they can take a long weekend. To find out if it's just an urban myth, BBC Science Focus asked analysts at transportation consultancy INRIX to go through the traffic flow data for London, Bristol, Cardiff, Edinburgh and Manchester.

And it seems it's true. Broadly speaking, travel times during rush hour are better on Friday mornings, and on Mondays, most likely for the same reason: people taking long weekends. The worst rush hours tend to be on Wednesday and Thursday afternoons – possibly because this is when most people are in the office, working to hit end-of-the-week deadlines. That said, just how bad the rush hour is for any individual driver depends on both the city and the roads being used. For example, some roads in Birmingham are even slower than London black spots. **RM**

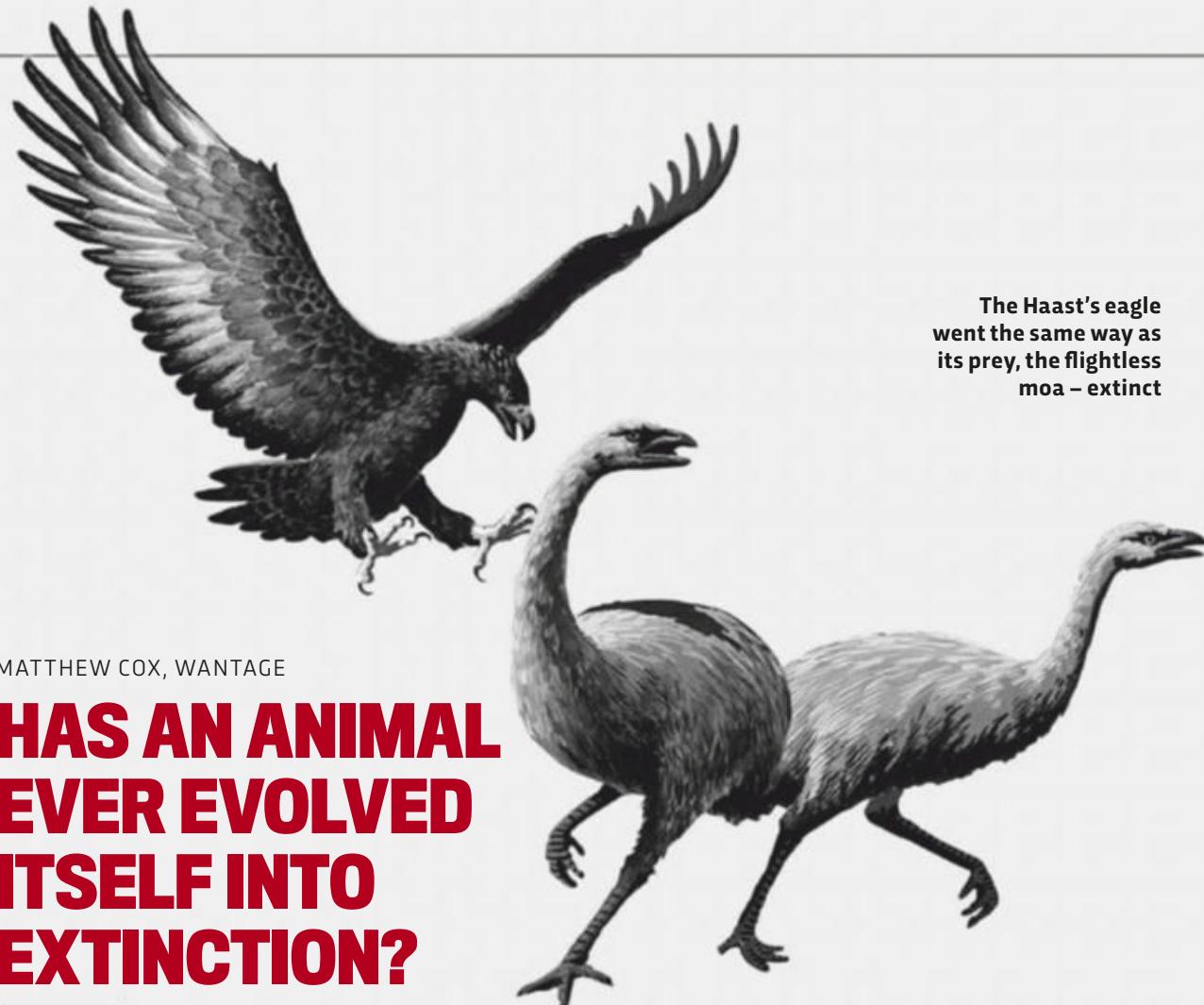
Rush hour average speed



JENNY PRICE,
WESTON-SUPER-MARE

IS IT POSSIBLE THAT MY IMMUNE SYSTEM HAS FOUGHT OFF DISEASES WITHOUT ME REALISING?

With each new breath, you take in about 50 potentially harmful bacteria. Virtually all of these are promptly destroyed by your immune system without you feeling a thing. But some bacteria and viruses can successfully infiltrate the body and lie dormant without causing any symptoms for many years until they suddenly flare up. Chlamydia infections, for example, show no symptoms for 50-70 per cent of women, because they lurk beneath the radar of the immune system. Any disease that your immune system does pick up, however, triggers swelling, inflammation and fever as the disease is fought, so that's something you will definitely notice. **LV**



MATTHEW COX, WANTAGE

HAS AN ANIMAL EVER EVOLVED ITSELF INTO EXTINCTION?

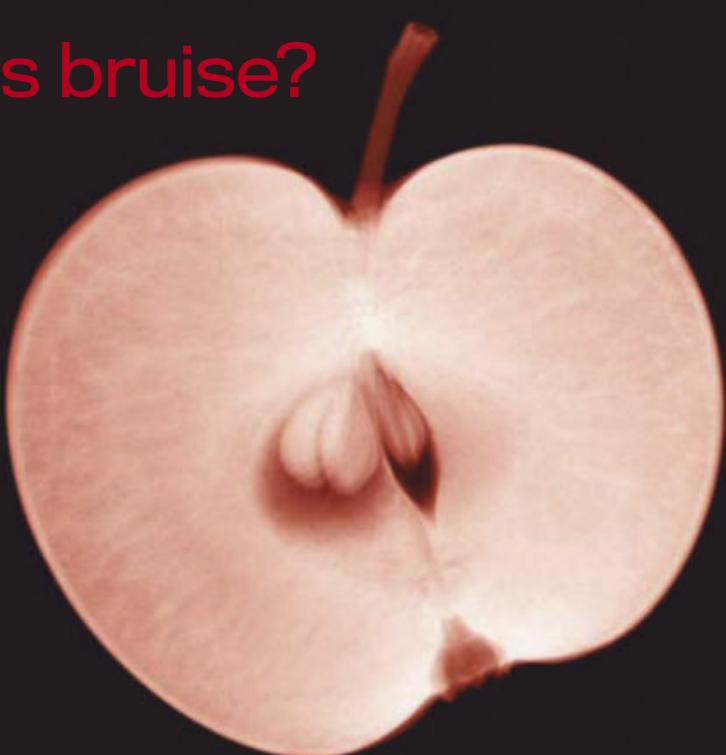
It's quite hard for a predator to drive itself extinct simply by being such a good hunter that it eats all of the available prey. Normally, evolution is a very slow process and predators are engaged in an ongoing arms race with their prey, who are also evolving new ways to escape. If the balance starts to shift in favour of the predator, the amount of available food dwindles and the predators aren't able to raise as many young. This allows the prey population to recover and equilibrium is restored.

But when a predator specialises to hunt a single prey species, it can get trapped in an evolutionary dead end. This happened to the Haast's eagle in New Zealand, which had evolved to prey exclusively on the flightless moa bird. When humans arrived in the 13th Century, the moa were hunted to extinction within 200 years. The Haast's eagle couldn't adapt to find new prey and went extinct too. This phenomenon, known as 'coextinction', is also common with parasites that have adapted to live on a single host animal. **LV**

FAYE LYNCH WILLIAMS (15 YEARS OLD)

Why do apples bruise?

Cutting or dropping an apple causes compartments inside the cells, including the central storage sacs (vacuoles), to burst open, allowing chemicals to mix and oxygen to flood in and catalyse reactions. In particular, chemicals in the vacuole called polyphenols come into contact with an enzyme called polyphenol oxidase, which is present in every cell in the apple. It's this reaction that leads to the brown, unappetising 'melanin' chemicals that we see on a sliced or bruised apple. **ED**



The Haast's eagle went the same way as its prey, the flightless moa – extinct

OLD WIVES' TALES...

MILK THISTLE CAN CURE HANGOVERS

People have taken milk thistle (*silybum marianum*) for liver disorders, such as hepatitis and cirrhosis, since the days of the Ancient Greeks. The main active ingredient is an antioxidant called silybin. Robust clinical evidence for its supposed effects is still lacking, but small-scale lab studies suggest that silybin may help to protect the liver from alcohol damage by, for instance, reducing the effect of damaging molecules called 'reactive oxygen species', levels of which are boosted by alcohol.

However, none of these studies supports the idea that silybin can help with a hangover, which involves different biological processes. When you drink, enzymes in your body first convert the alcohol into a toxic, carcinogenic chemical called acetaldehyde. An enzyme called aldehyde dehydrogenase then converts acetaldehyde into acetate, which can break down to form water and carbon dioxide. But if you've consumed excessive alcohol, acetaldehyde builds up because there's not enough enzyme to deal with it. This increase in toxic chemicals is a major contributor to the nausea and headaches you feel the morning after.

There is, however, no evidence that milk thistle can reduce acetaldehyde levels, and there's no magic way to avoid a hangover. Just make sure you eat before hitting the alcohol and drink plenty of water before you go to bed. **ED**





I CAN'T STOP SMELLING MY SOCKS. AM I WEIRD?

Not at all. Many of us like to whiff smelly things. It's a form of what psychologists call 'benign masochism'. The minor thrill of a nasty smell has been likened to the adrenaline rush we get from rollercoasters. Even though we've been warned that the experience will be unpleasant, we know it won't be seriously harmful, so it provides a way for us to test out experiences and emotions in safety. Be careful when it comes to your socks, though – they might be harbouring fungal spores. A 37-year-old man in China was hospitalised last year with a lung infection attributed to his compulsive sock-sniffing. **LV**



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY SCIENCE FOCUS EXPERTS

MY FRIENDS CALL ME 'HUMPTY DUMPTY' BECAUSE I'M ALWAYS FALLING OVER. CAN MY CLUMSINESS BE CURED?

Yes, there is hope for you. Research with injury-prone athletes suggests that the root cause of clumsiness often lies in the mind – stress can dull reflexes and narrow our focus, making us less aware of our surroundings and less able to react appropriately when we bump into



things or fall awkwardly. Lower your stress levels and your Humpty Dumpty days may soon be over. But if your problems are serious and chronic, it's possible that you have dyspraxia. This brain disorder affects movement control and coordination. Visit your GP if you are concerned, or visit dyspraxiafoundation.org.uk **CJ**

LIKE A LAMB INTO A PRIDE OF LIONS, I'M ENTERING THE WORLD OF ONLINE DATING. HOW DO I IMPROVE MY CHANCES OF GETTING A MATCH?

Fear not, there is a surprising amount of research into the effectiveness of different dating profiles – a recent review identified over 80 relevant studies! It turns out that even your username can make a difference: heterosexual men are attracted to women with names that imply attractiveness (such as 'hottie87'), whereas heterosexual women tend to go for men with names that imply intelligence and class

(like 'educated-matt'). In terms of your profile picture, you'll be seen as more attractive if you have a genuine smile and are looking at the camera. If you include other pics, it helps to present yourself around other people who appear to be having a good time. When it comes to your bio, the optimal ratio is apparently to devote 70 per cent of the description to yourself and 30 per cent to the kind of person you're looking for. Also, rather

than claiming that you have a good sense of humour and that you're smart, it's more effective to demonstrate your wit and intellect in what you write. Generally speaking, people are drawn to similarity, so if you're cunning you could first identify someone you're interested in and then compose a profile that accentuates what you have in common – but beware, if you lie, this is likely to backfire further down the line! **CJ**

EDWARD SEYMOUR,
HOVE

COULD TWO PLANETS SHARE THE SAME ORBIT WITHOUT COLLIDING?

The definition of a planet includes the proviso that it has 'cleared its orbit' of other large bodies. So, strictly speaking, two 'planets' in the same orbit would not be classed as planets. But it is possible for two planet-like bodies to share the same orbit around a central star without colliding: the second object would need to be positioned at a particular point in the first object's gravitational field. At this 'Lagrange point', the centrifugal and gravitational forces acting on the second object are such that it follows the same orbit as the first object. However, for large objects, such a precise orbital configuration is unlikely to remain stable for very long. Indeed, the Earth may have had a co-orbital companion early in its history, with which it soon collided, possibly forming the Moon. There are, though, several examples of smaller bodies sharing a planet's orbit, such as the Trojan asteroids, which follow Jupiter's path around the Sun. **AGu**



MAURICE GEORGE, ORMSKIRK, LANCASHIRE

IS IT TRUE THAT WEATHER CAN AFFECT THE BEHAVIOUR OF A CRICKET BALL?

Many cricket players, fans and commentators believe that certain atmospheric conditions, in particular high humidity or cloud cover, contribute to a cricket ball's 'swing', where the ball veers sideways as it approaches the batter. Swing occurs when there is a different airflow on either side of the ball, which can result from a number of factors, including an asymmetry in the roughness of the ball (players encourage this by polishing one side and not the other), the alignment of the ball's seam relative to the ball's path, and the bowler's action. Humid, overcast conditions are also often said to play a role by affecting the density of the air, but studies have repeatedly failed to find any relationship between the weather and increased swing, suggesting that any effect is negligible. **AFC**

70

The height in centimetres an adult froghopper (an insect that grows to a length of about 6mm) can jump vertically.

EMAIL YOUR QUESTIONS TO QUESTIONS@SCIENCEFOCUS.COM

DAVID KING, WYMONDHAM, NORFOLK

HOW IS THE TIME DISPLAYED ON MY LAPTOP REGULATED AND MAINTAINED?

Most computers today use the Network Time Protocol to set their clocks. NTP is a special set of rules for communicating between computers over the internet, designed to synchronise clocks to the Coordinated Universal Time (UTC). It takes time for messages to travel over the internet, so NTP takes this delay into account when computers are communicating the time with one another. In operation since 1985, NTP is one of the longest running, continuously operating, internet protocols. **PB**



LOTTIE ROESSLER, VIA EMAIL

WHAT DOES WATER TASTE OF?

Pure water doesn't stimulate your taste buds directly, but it can sometimes still have a taste. That's because your tongue becomes habituated to the taste of the chemicals in your saliva. When you rinse those away with water, your taste receptors will 'rebound' with an opposite taste sensation. So since your saliva is salty, water can taste slightly sweet or even bitter. **LV**

WHAT CONNECTS

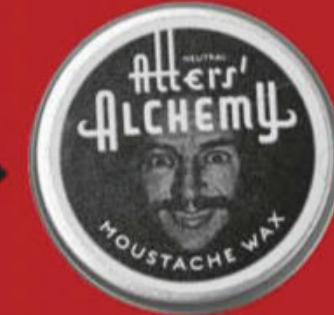
SHEEP AND SALVADOR DALÍ?



Sheep produce an oily substance called lanolin from their skin to waterproof their fleece. Lanolin is a mixture of up to 20,000 long-chain hydrocarbon compounds.



The fleece from one sheep contains about 275ml of lanolin. Before the fleece can be spun into wool, the lanolin must be removed by washing in hot water and then centrifuging.



The extracted lanolin is used in hundreds of different applications, from nipple cream to the lubricant on trombone slides. It's also an ingredient in some moustache waxes.



The artist Salvador Dalí claimed to use the same brand of moustache wax as Marcel Proust. In 2010, Dalí's iconic, meticulously waxed moustache was voted the most famous moustache of all time.

STM CASE STUDY



Thierry Delaitre, head of ICT developments, explains how STM is protecting tech investment at the University of Westminster

Protection is key

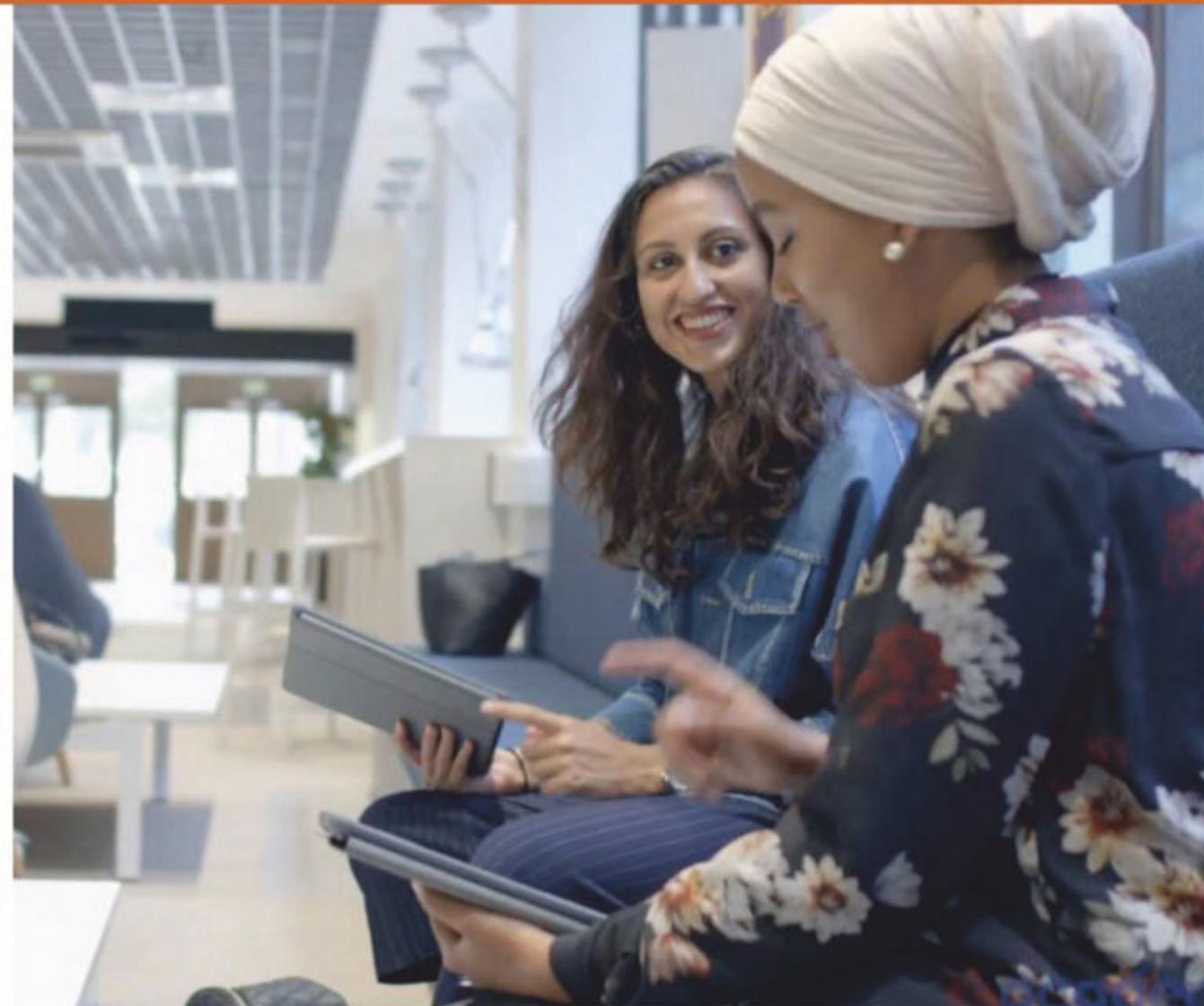
With 3,000+ mobile devices rolled out to students and staff since 2014/15, The University of Westminster truly understands the need to protect its tech investment. Starting with a deployment in the University's Faculty of Science and Technology – where 270 mobile devices were provided to staff in 2014 – the Mobile Learning Project saw a further 2,000 mobile devices rolled out to students in 2015. Due to this successful implementation, 1,000 more student devices were delivered in 2016. At each stage, device protection was a key consideration – saving time and money, and enabling the successful recycling of mobile devices to new students, plus contributing to the sustainability of this project.

Crucial design features

The STM Dux case was selected to protect iPads and other mobile devices for staff and students. Not only does the STM Dux's reinforced corners protect the iPad from inadvertent drops, its transparent back cover allows the University asset tag to be visible at all times. Design features like these – plus being insurance approved – have ensured STM remains the de facto choice for device protection at UoW, and an integral part of the Mobile Learning Project.

Tangible measures

Outside of cost, the most significant impact of protecting devices with Dux was the decrease in downtime. While the presence of the FST Helpdesk enables a speedy replacement iPad in the event a device needs to be repaired, it's the time not lost by students with a broken device that's made the most significant difference. Historically, the majority of damaged devices were due to cracked screens – either by being dropped or lack of protection in standard bags. Since the adoption of STM, device breakages have been less than 0.05%, thanks in no small part to the military-tested protection the Dux can give you against accidental damage.



Lifetime protection

In partnership with independent advisors, 4C Strategies, who provided programme management assistance for the university's managed service provision, there was a responsibility to bear in mind for the life of each iPad from an insurance and warranty perspective. Particular attention was given to identify best value for money, but also the long-term protection of the devices.

The primary choice

The hardware protection choice these days is vast, so selecting the most appropriate option can seem like a minefield – and in any teaching environment, broken devices means disrupted classrooms and a loss of valuable teaching time. Once the due diligence was complete, there was no hesitation in choosing the STM Dux as primary choice for protection and ensuring the University of Westminster's Mobile Learning Project was a tremendous success.

Get Your 'Dux' in a Row with STM

"Since the adoption of STM, device breakages have been less than 0.05%, thanks in no small part to the militarytested protection"

Thierry Delaitre –
head of ICT developments,
University of Westminster

**For further information,
please call 01256 378 690**





Military grade iPad protection

dux plus

for all iPad Pro models



The **dux plus** provides best-in-class protection for your iPad Pro. Along with integrated Apple Pencil Storage the dux plus features a patented magnetic closure, reinforced corners and transparent back panel to protect your iPad from inadvertent drops.



Also available for all iPad models in Black, Blue & Red, including new 2018 11" & 12.9" iPad Pro.

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Albion

Apple Store

JIGSAW24

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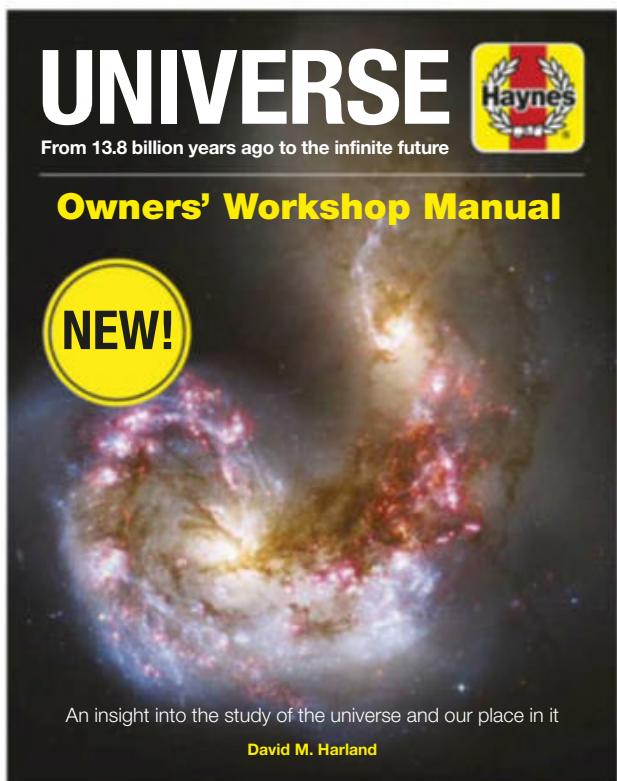
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dna.science

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH



1. Go underwater

Broadcasting from the US, the Bahamas and Australia's Great Barrier Reef, *Blue Planet Live* will dive deep into the environmental crisis unfolding in the Earth's oceans.

Blue Planet Live
BBC One, March
Find out more on p52

2. Fold a phone

Samsung's brand-new, foldable smartphone is slated to hit the shops in early May. It packs in six cameras and can display three apps on its screen at once. And it folds!

Samsung Galaxy Fold
From £1,500 approx,
samsung.com

3. Hit the trails

Inov-8 has infused graphene, the world's strongest material, into the fang-like rubber studs on their new trail shoe. Inov-8 claims the graphene makes the studs 50 per cent harder wearing.

Inov-8 Mudclaw G 260
£140, inov-8.com

4. Slow down

Did you know humans experience time twice as fast as a leatherback turtle does? This BBC Radio 4 show investigates why animals all experience time on different scales.

A Sense Of Time
BBC Radio 4, 3 April
Find out more on p90

5. Classic cinema

Grab your popcorn and enjoy the original *Jurassic Park* in the Natural History Museum's Hintze Hall, underneath the watchful eye of Hope, the giant blue whale skeleton.

Jurassic Park
12 March
[£27.75, thelunacinema.com](http://thelunacinema.com)

6. Leave the lab

Explore science outside of the traditional lab, and see what can be done when scientists, artists, activists and technologists pioneer new ways of engaging in research. Opens 16 March.

Open Labs
Science Gallery Dublin
dublin.sciencegallery.com



Flies process images at four times the speed that we do p90

£10.8BN

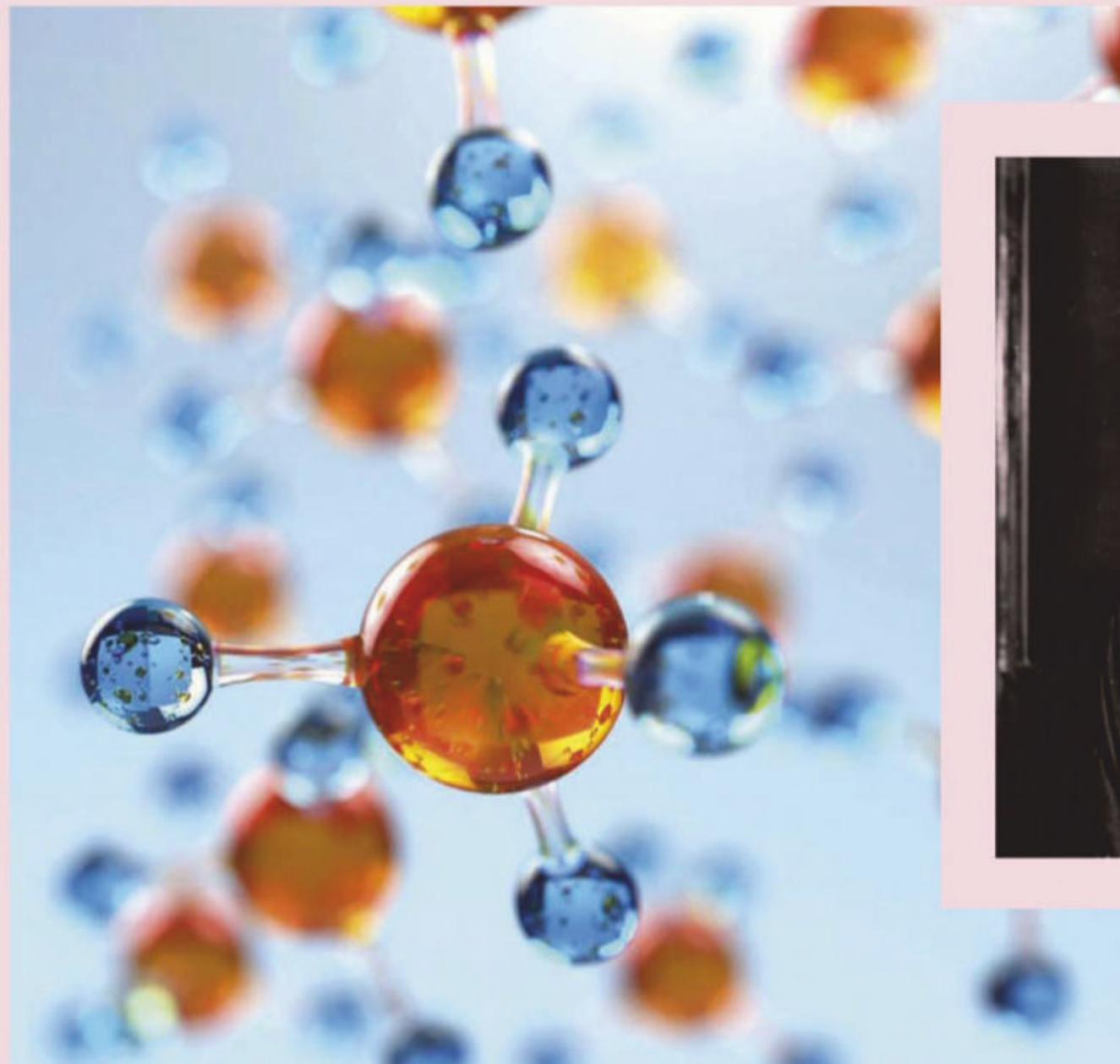
It's predicted that £10.8bn will be spent on smart home devices in the UK in 2019, all of which could be vulnerable to hackers p93



Profile

EXPLAINING LIFE WITH PHYSICS

IN THE DEMON IN THE MACHINE, PHYSICIST PAUL DAVIES EXPLORES AN EMERGING AREA OF RESEARCH THAT AIMS TO MERGE PHYSICS AND BIOLOGY, TO EXPLAIN HOW LIFE BEGAN

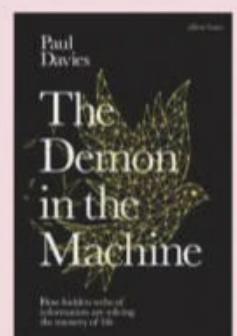


“Schrödinger had to admit that, in spite of his brilliance, he still found life very baffling, looked at through the eyes of a physicist”

Even 75 years on, and in spite of the extraordinary advances in biology during that period of time, nobody knows what life is or how it began. But I think, just in the last few years, we've seen a little crack in the wall of mystery that shrouds life. I think we are now beginning to see what makes life tick.

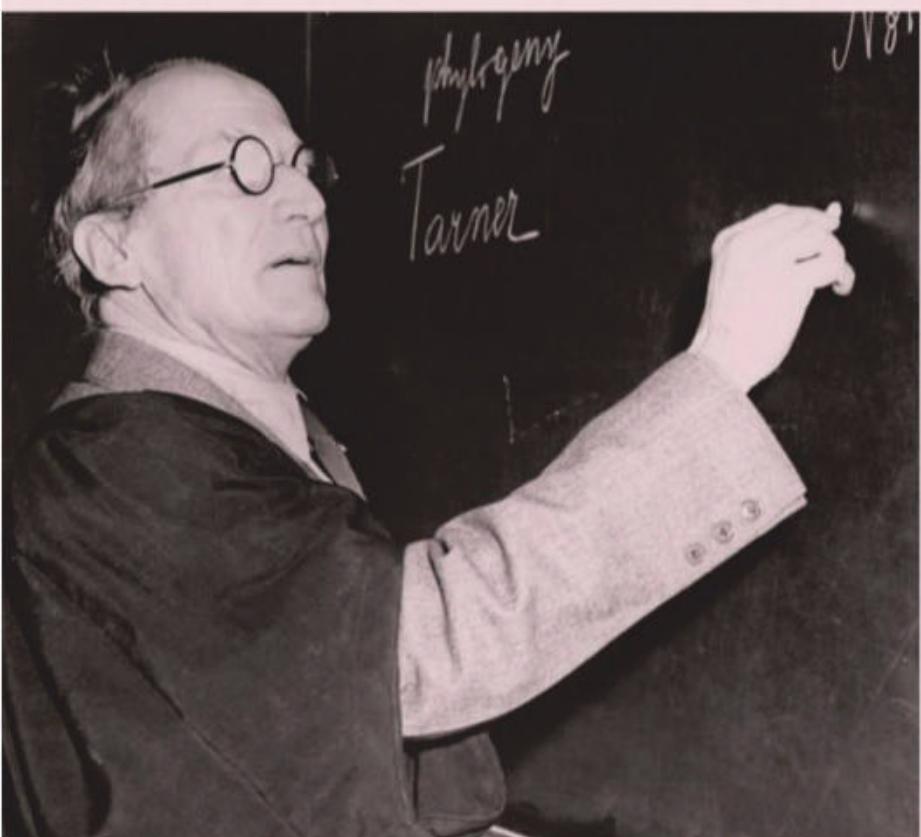
**WHY DO WE NEED A NEW TYPE OF LAW?
WHAT'S WRONG WITH THE PHYSICS THAT WE HAVE NOW?**

Biologists think of life in terms of information, that is, information storage and processing. They cast a



THE DEMON IN THE MACHINE

BY PAUL DAVIES
(£20, ALLEN LANE)



ABOVE: Erwin Schrödinger

LEFT: Physics is adapted to the level of molecules and particles, but not to a system as a whole

narrative in terms of things like coded information. Your DNA, for example, is packed full of coded information – instructions, translation, transcription, editing, and signalling. The biosphere is like the original world wide web. When you talk to physicists or chemists about life, they will talk in terms of intermolecular forces and shapes, entropy, binding energies, and forces, that sort of thing. So, we have twin narratives, but it's clear that the physics narrative is adapted really just to the level of individual particles and molecules. It doesn't adapt well to the system as a whole. Information, I think, provides the bridge that can unite physics and biology. We need new physics because we need to incorporate information, not just as a way of speaking, but as a physical variable into fundamental physics.

A LOT OF US THINK OF INFORMATION AS WHAT'S STORED IN COMPUTERS. HOW CAN A LIVING THING CONTAIN INFORMATION?

It seems to me that a living cell is really a supercomputer, and of course a brain is also an incredible computational system. Maybe it isn't too much like a digital computer but it's certainly processing huge amounts of information. The computer analogy is a close one.

The difficulty is not so much being persuaded that information is the key to biology, it is trying to understand how information can be incorporated into physics. I believe that the way forward was already shown to us

over 150 years ago by mathematical physicist James Clerk Maxwell and his famous demon.

WHAT WAS MAXWELL'S DEMON?

Maxwell envisaged a tiny being – this was, I should hasten to add, a thought experiment – who could perceive individual molecules in their motion, and use a device that wouldn't expend any energy, but would be able to sort these molecules into fast and slow. So, he could put the fast-moving molecules on one side and slow-moving molecules on the other.

Because temperature is a measure of molecular speed, in effect that would create a temperature gradient, from which some sort of heat engine could be operated to do useful work. So, Maxwell's demon is capable of creating a sort of perpetual motion machine, able to run a device to do useful work just from the heat energy of a gas, in flagrant violation of the cherished second law of thermodynamics. This second law normally says that heat flows only from hot to cold. What Maxwell's demon does is allow heat to flow backwards – reverse the arrow of time, if you like – by using information about the molecular speed.

WHAT DOES MAXWELL'S DEMON TELL US ABOUT LIFE?

Well, it turns out that living organisms are packed full of Maxwell demons. They are in your body as I speak to you. They are chuntering away, manipulating energy and garnering information, processing it and responding. You are full of tiny little molecular machines. These machines, while they don't break the second law of thermodynamics, are playing the margins of it, achieving extraordinary levels of efficiency. That's one of the reasons why the human brain – though it's got the capability of a supercomputer, which would consume megawatts of electricity – runs on the equivalent of just a small lightbulb.

CAN WE THINK OF INFORMATION AS A DRIVING FORCE FOR LIFE?

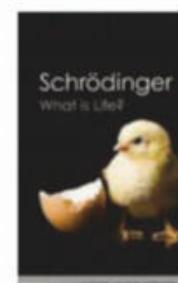
So, am I saying that information is a type of 'life force'? Well, the word 'force' has bad connotations in connection with life because, in the 19th Century, it was widely believed that the secret to life was some sort of special substance or essence that infused matter and, sort of, brought it to life. The life force was, I think, associated in many people's minds with psychic phenomena or spiritualism or something of that sort, so it got a bad press. And unless you can measure this force, it doesn't really help you with an explanation. So, information isn't a force: it's a more subtle concept.

DR PAUL DAVIES

Paul is a theoretical physicist, cosmologist and science communicator. He is based at Arizona State University.

Interviewed by BBC Science Focus online assistant Sara Rigby.

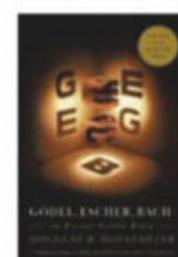
Author's bookshelf



WHAT IS LIFE?

BY ERWIN SCHRÖDINGER
 (£14.99, CAMBRIDGE UNIVERSITY PRESS)

This laid the foundations of molecular biology, written by the physicist who co-founded quantum mechanics. I read it as a student and thought, "Yes, life is pretty weird!"



GÖDEL, ESCHER, BACH: AN ETERNAL GOLDEN BRAID

BY DOUGLAS HOFSTADTER
 (£19.99, BASIC BOOKS)

This book addresses how wholes and parts can relate to each other in strange and counterintuitive ways.



CONSCIOUSNESS EXPLAINED

BY DANIEL DENNETT
 (£12.99, PENGUIN BOOKS LTD)

A heroic attempt to explain – some might say explain away – the nature of consciousness. It's written by a distinguished philosopher in a popular style. There's much food for thought.

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH



WHAT I'M LISTENING TO

Helen Glenny
EDITORIAL ASSISTANT

A SENSE OF TIME

BBC RADIO 4, 3 APRIL

I'd always thought of time as constant, but after talking to the BBC Radio 4 team about their upcoming show *A Sense Of Time*, I'm reconsidering.

According to the Radio 4 team, we experience time at twice the speed of a leatherback turtle. Swifts and flies, on the other hand, process things even faster than we do, allowing them to dodge branches in a forest at speed or avoid a swatting hand. Swordfish have the process of manipulating time nailed: they can alter their sense of time by heating up or cooling down their brains. It sounds fantastic. Speed up time on a long cross-ocean commute, or slow it down when you're hunting prey, when every second counts. What's more, presenter Geoff Marsh and the Radio 4 team are suggesting that humans might have similar powers. When you're in a meeting and your boss asks you a question, but you haven't been paying attention, time slows almost to a halt as you scramble for an answer. So maybe we slow time when we're afraid? Marsh explores this in a radical fashion, by attempting to present the show while bungee jumping. That's worth tuning in for.

MORE OR LESS

BBC RADIO 4

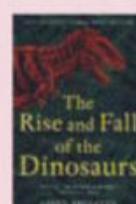
More Or Less goes like this: an unbelievable statistic pops up (1 in 20 adults in Britain don't believe the Holocaust took place, or 15,000 people have liked your Tinder profile), so

economist Tim Harford and his team find out where that number came from and whether we can believe it. Sometimes it's good news, sometimes it's bad: while the team is sceptical about that rate of Holocaust deniers, the same is true about your Tinder likes.



WHAT I'M READING

Jason Goodyer
COMMISSIONING EDITOR



THE RISE AND FALL OF THE DINOSAURS

BY STEPHEN BRUSATTE
 (£9.99, PAN MACMILLAN)

Anyone who is still clinging onto the popular culture notion that dinosaurs were slow, drab, dim-witted reptilians that sleepwalked their lives into extinction and merit little further study really needs to pick up this book.

Through just over 300 pages, we learn that, far from being a dead subject, palaeontology is entering into an exciting golden age in which new species of dinosaurs are being unearthed around the globe every week. And that thanks to cutting-edge technologies such as CAT scanners and 3D animation software, we are finding out more than ever about some of our old favourites: Who knew that the *T. rex* was similar in intelligence to a modern-day chimpanzee, and therefore smarter than dogs or cats? Or that the *Velociraptor* made famous by *Jurassic Park* was not scaly at all but covered in frilly eagle-like features?

Along the way, Brusatte recounts the epic story of the dinosaurs' rise to world domination all the way through to their eventual, abrupt demise.



WHAT I'M PLAYING

Alexander McNamara
ONLINE EDITOR

SHADOW GHOST

£109.95 + MONTHLY SUBSCRIPTION FROM £26.95
SHADOW.TECH

As much as I would love to spend many thousands of pounds of my hard-earned cash on a top-of-the-line gaming computer, alas, boring things like mortgages get in the way. However, this month I've toyed with the Shadow Ghost streaming box, which lets you stream games over the internet.

At first glance, you be forgiven for thinking there is no way this curvy box could run anything more advanced than *Minesweeper*, let alone the latest games with settings pushed to max. And yeah, you're right, but then that's not what the Ghost does.

Similar to how Netflix or Amazon Prime stream films and TV shows from the Cloud, the Ghost streams games from a super-powered PC, packing 3.2GHz Xeon processor, 12GB RAM and a NVIDIA GTX 1080 graphics card directly to your television.

Everything looks stunning, and as long as you have a robust and speedy internet connection, you can game away to your heart's content without any noticeable lag or glitches.





WHAT I'M READING

James Lloyd

STAFF WRITER



CAN SCIENCE EXPLAIN EVERYTHING?

BY JOHN C LENNOX
 (£7.99, THE GOOD BOOK COMPANY)

Can religion and science mix? That's the question at the heart of a new book by John Lennox, a mathematician who is also a Christian. I approached Lennox's book with some trepidation. I was brought up as a Christian, but as I became more and more interested in science, the two areas began to seem less and less compatible. Science is a world of facts and testable theories. Religion is a world of philosophical arguments, and at some point, logical

argument seems to break down. There's no experiment on Earth that could prove the existence of the soul, or a god, and so religion often seems, to me, to require a leap of faith – a jump into the unknowable – that is at odds with the scientific worldview.

There are plenty of religious scientists out there, though, and Lennox – who is emeritus professor of mathematics at the University of Oxford – points to a long line of believing thinkers, including Johannes Kepler and Isaac Newton. One of Lennox's central messages is that science can answer the how's and what's, but it doesn't do so well at the why's. The Big Bang provides a pretty good explanation of how the Universe began, but who can say why it happened? That, he argues, is where religion (or more specifically in Lennox's case, Christianity) can fill the gaps. Of course, we might not even

need a 'why' in the first place, in which case this argument doesn't hold water.

How about the apparent conflict between, for example, the Bible's account of Creation and the scientific theories of evolution and the Big Bang? Lennox argues that some parts of the Bible can be taken as a metaphor, and that there's no reason why the two views can't coexist. Later on, he turns to more literal aspects of the Bible, offering some compelling historical evidence for the reliability of the New Testament's account of Jesus' life.

I've always seen miracles as one of the major stumbling blocks to religion. Lennox's argument is that a God who created the Universe could easily decide to suspend the laws of physics and perform the incredible feats detailed in the Bible, including the resurrection of Jesus. Here, it feels like Lennox has made the leap of faith, and is asking us to follow. I'm still sitting on the fence...

Detail of a mosaic in the crypt at the Musee Pasteur. This is where Louis Pasteur, who invented pasteurisation, is buried

Private life

THESE GADGETS HELP YOU ENJOY THE BENEFITS OF A SMART HOME WITHOUT RISKING YOUR SAFETY



AMAZON ECHO

Amazon has "pretty much got it nailed" when it comes to security, according to security expert Ken Munro (see interview, right). Moreover, a big company like Amazon has a reputation on the line, so you're more likely to get your privacy concerns addressed than if you went with a new start-up. They've even been asked to hand over Alexa recordings to a judge in a murder case, but won't do so "without a valid and binding legal demand properly served on us." Security-wise, they've got your back.

£69.99, AMAZON.CO.UK



PHILIPS AVENT SCD630/26 VIDEO BABY MONITOR

Baby monitors have been hacked by criminals, allowing footage from the devices to be streamed online. This one randomly changes the frequency the monitor is using to communicate, making it harder to hack.

£170, PHILIPS.CO.UK



DARKMATTER KATIM

Touted as the world's most secure smartphone, the Katim is named after the Arabic word for silence. You can flick a switch to immediately turn on 'shield mode', which physically disconnects power from all recording services, like your phone's microphone and cameras.

£TBA, DARKMATTER.AE



NEST LEARNING THERMOSTAT 3RD GEN

Nest was acquired by Google in 2014. This means it now falls under Google's Vulnerability Reward Program, where researchers get money for finding flaws in their services. All third-party devices that work with Nest are subject to a rigorous certification process.

FROM £219, NEST.COM



ASUS RT-AC88U WIRELESS ROUTER

This is one the most secure wireless routers on the market. It has no default passwords (an easy target for hackers), it automatically detects vulnerabilities in your network, lets you set up parental controls, and identifies malicious sites before you've reached them.

£269, ASUS.COM

Troubleshoot

SMART HOME SECURITY



MANY OF US ARE BUYING SMART HOME DEVICES, BUT ARE WE SIGNING AWAY OUR SAFETY? SECURITY EXPERT KEN MUNRO REVEALS ALL

WHAT RISKS COME WITH SMART GADGETS?

The number one risk is invasion of privacy. If you've got smart cameras, or any device that's listening to you, there's a chance those can be hijacked and you can get spied on. We [my company, Pen Test Partners] found vulnerabilities in in house security cameras, baby monitors and smart home assistants.

We looked at an interactive kids' doll that has a microphone and speaker, and connects to your phone via Bluetooth. When you connect to the doll there is no PIN, which means that anyone within Bluetooth range, 30, 40, 50 metres away, can connect. That means that someone outside on the street or in the next house can listen to the microphone and spy on your kids, and can talk to them as well.

We've also documented cases of people being stalked through smart tech: there was a case with a doorbell last year where an ex partner was monitoring someone's every movement. One of the challenges with that is that there's no way to know it's happening.

Things get really freaky when your home gets hijacked. We showed, a few years ago, the very first case of ransomware being loaded onto a smart thermostat. It's all about a loss of control. You lost control of your heating system, so what? But what if that was your car? What if that was a life support system? That's

where things get scary. What if it's your smart door locks and you can't get in or out of your own house? One smart lock vendor's systems crashed, and people couldn't get into their houses – and that wasn't even hacking, it just crashed.

In other cases, a combination of devices can make your home vulnerable. Amazon Echo, for example, is pretty secure. But other things around your home can allow people to take control through the Echo. Google Chromecast has a bug in it that they're now fixing, four years after it was found, that allows someone to drive past your house, connect to your Chromecast with a little bit of clever hacking, and cast a YouTube video that says things to your Echo, like 'Alexa, turn off the lights.'

WHAT'S THE POINT OF THESE ATTACKS?

Sometimes people just do it because they can. You're just a system on the internet, and someone thinks it'd be fun to mess around with your home. But there are also cases where people might be trying to achieve more. We speculate that if you attack lots of people's thermostats concurrently you can cause power spikes and knock over the electricity grid.

ARE SMART GADGETS REGULATED IN ANY WAY?

There's nothing yet, but the EU is making great leaps forward. In the UK we've got the promise of regulations from the Department of Culture, Media and Sport. In California, regulation comes into force in 2020. The problems we keep finding are basic things, so we need just basic controls around not having back doors that hackers can exploit, keeping software up to date so it doesn't become vulnerable, and helping consumers secure themselves – not letting people set silly passwords, for example. We need consumer efforts, manufacturer efforts and regulator efforts. We need a bit of everything.

WHAT SHOULD WE LOOK FOR WHEN WE'RE BUYING SMART HOME TECH?

The better known brands are actually very secure – Amazon and Google by and large have their security sorted. Big brand names have a huge incentive to get it right to protect their

X

"It's all about a loss of control. You lost control of your heating system – so what? But what if that was your car? What if that was a life support system?"

reputation. The problem comes from the new entrants to market, the start ups. That's when security gets a bit more random. We've seen some excellent security in start ups and new entrants, but we've seen some horrific security, and it's difficult for the consumer to know which product is going to be good and which product is going to be bad.

HOW CAN WE PROTECT OURSELVES?

First of all, when buying a product, ask yourself if you need it. Are you willing to gamble your privacy for the sake of being about to turn something off and on remotely? There are some fantastic smart products out there that, for example, allow you to be more efficient with your energy. So if you decide you need it, make sure you set up a strong password for it, and don't use the one you use somewhere else. Write it down somewhere privately, or use a tool called a password manager that does it all for you. Lastly, keep everything up to date. When updates come out for your computer, your phone, or your apps, they're there to fix security flaws, so if you don't apply them, your product is becoming more vulnerable.

KEN MUNRO @TheKenMunroShow

Ken works at Pen Test Partners, a firm that researches and tests the security of 'smart' devices. **Interviewed by BBC Science Focus editorial assistant Helen Glenny.**

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF
BBC SCIENCE FOCUS WITH THESE BOOKS, WEBSITES AND SHOWS

Reality check p32

AIR POLLUTION IN THE WORLD

Real-time air quality index
aqicn.org

AIR POLLUTION IS KILLING US, HERE'S HOW YOU CAN STOP IT

In this episode of the *Science Focus* podcast, pollution scientist Gary Fuller explains how bad our air is and how we can stop this invisible killer.
bit.ly/stop_air_pollution

THE FOUR-DAY WEEK

Economist Lord Robert Skidelsky tells Helen Lewis about the four-day working week in this episode of BBC Sounds.
bit.ly/four_day_working_week

LOST IN A GOOD GAME

BY PETE ETCHELLS (£13.64, ICON BOOKS)

In this book, journey through the development of computer games, experience the highs and lows of gaming, and find out why it isn't as antisocial as it may seem.

Oldest galaxies in the Universe p46

BIG BANG LADYBIRD EXPERT BOOK

BY MARCUS CHOWN (£7.99, MICHAEL JOSEPH)

This accessible book addresses all your questions about the Big Bang, such as why the Universe is expanding, where the Universe came from, and what elements made up the Big Bang.

THE BEGINNING AND THE END OF EVERYTHING

BY PAUL PARSONS (£16.99, MICHAEL O' MARA)

Go on a rollercoaster ride to the beginning of the Universe, 13.8 billion years ago. Find out what's in store for the future of the cosmos – will we burn out or fade away? Are we just a tiny part of a sprawling multiverse?

RELICS PROJECT

Discover more about the science behind the RELICS project.
relics.stsci.edu

Chris Packham interview p52

BLUE PLANET II

Revisit the incredible underwater world that Sir David Attenborough brought to our screens in 2017, and get up to speed on the ocean's threats ahead of *Blue Planet Live*.

bit.ly/blue_planet_2

The hidden power of your brain p60

HARNESSING THE POWER OF PLACEBOS

How much does the mind play a role when we're receiving medical treatment? In this TED talk, Dr Alia Crum, principal investigator in the Mind and Body Lab at Stanford University, makes the convincing argument that often subconscious thoughts about the credibility of the doctor and how friendly they are play a huge role and we should learn to harness this more effectively.
bit.ly/placebo_power

THREE WORDS THAT WILL CHANGE YOUR LIFE

In this TED talk, Dr Mark Holder, a psychologist at the University of British Columbia in Canada, talks about the science of happiness. Discover how modern life threatens happiness, how we can make ourselves happier and the powerful effect it can have on us.
bit.ly/three_words

FOR MORE, FOLLOW US



Why do charismatic leaders fail upwards? p70

WHY INCOMPETENT PEOPLE THINK THEY'RE AMAZING

In this TED-Ed talk, psychologist Dr David Dunning discusses the Dunning-Kruger effect and explains why we're so bad at evaluating ourselves accurately.

bit.ly/fail_upwards

PRE-SUASION: A REVOLUTIONARY NEW WAY TO INFLUENCE AND PERSUADE

BY ROBERT CIALDINI (£4.99, SIMON & SCHUSTER)

Learn some of the tricks of your favourite charismatic leaders in *Pre-Suasion*, where Prof Robert Cialdini outlines the seemingly insignificant details that make you receptive to an idea before you've even heard it.

CHARISMA: PINNING DOWN THE BUTTERFLY

In this 12-part podcast series, Francine Stock looks to understand the allure of charismatic figures, from Mandela's humility- and service-based appeal to Hitler's 'dark charisma'.

bit.ly/science_of_charisma

Radar p87

CAN SCIENCE EXPLAIN EVERYTHING?

James Lloyd interviews John C Lennox on the *Science Focus* podcast.

sciencefocus.com/science_focus_podcast

SMART HOME SECURITY

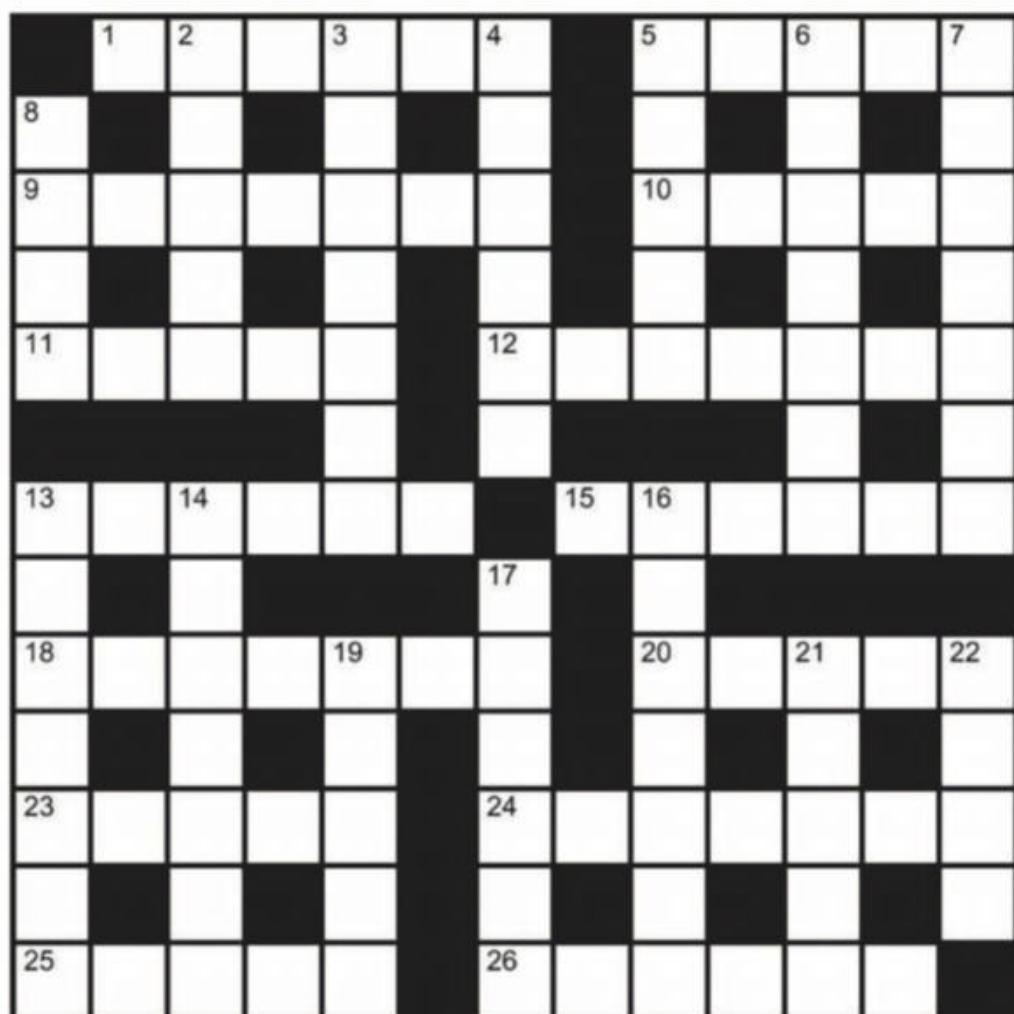
Watch a TEDx talk with internet security expert Ken Munro about the safety of home automation technology.

bit.ly/smarthome_security_

NEXT ISSUE

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Malt mixed with copper powder (6)
- 5 Fellow managed to get caught with old money (5)
- 9 Returning star to maul unfortunate former pupil (7)
- 10 Tarmac, cement, taking back holy site (5)
- 11 Father swaps it with old terrace (5)
- 12 Mention rugby player is in spaceship entry system (3,4)
- 13 Enhanced human about to go by, working with resistance (6)
- 15 Hungarian periodical – 12 months, no English (6)
- 18 Marine transported large rock (7)
- 20 Bay for a snack, we hear (5)
- 23 Circular sandwiches (5)
- 24 Involved an obsession (7)
- 25 Stare wildly at flower (5)
- 26 Recipe includes a new pastry (6)

DOWN

- 2 Nowadays university student has time to be grown-up (5)
- 3 Prisoner gets travel form (7)
- 4 Some grapes are capital (6)
- 5 Largest supporter adds iron to rum cocktail (5)
- 6 Can somehow shove skin off unknown fish (7)
- 7 Great joke where a terrible one is usually found (7)
- 8 Insect has been quiet (4)
- 13 Spies union doctor registered in county (7)
- 14 Stop search without small feast (7)
- 16 Record directions on the white bit (7)
- 17 Calm lap travelled by detectives (6)
- 19 Equestrian clause (5)
- 21 Guy almost finds the French a shade heraldic (5)
- 22 Message from furthest extremity (4)

GETTY IMAGES

A N S W E R S

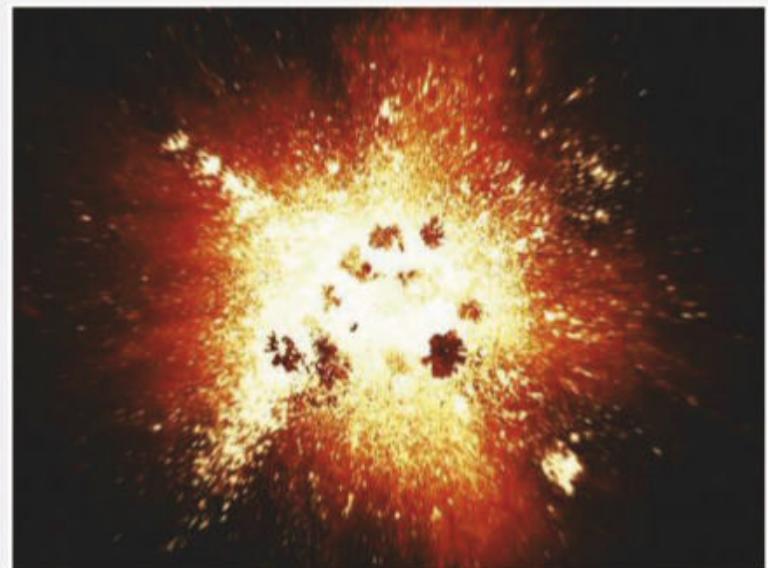
For the answers, visit bit.ly/BBCFocusCW

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COVER STORY

BEFORE THE BIG BANG

Who says it was the beginning of everything? Explore what came before



PLUS

DEMENTIA ON THE MENU

Michelin-starred chef employs an entire restaurant team with dementia, and that's just for starters

INTERVIEW

DAVID ATTENBOROUGH

The man, the legend, the embodiment of humanity's better angels, David Attenborough gets optimistic

ON SALE 3 APRIL



Discovery Guide

Immerse yourself in the world of science this year with your pick of festivals and courses.



CHELTEHAM SCIENCE FESTIVAL

4 – 9 JUNE 2019

Fascinating talks and hundreds of free hands-on activities exploring wellbeing wonders of the everyday world, mysteries of the universe and cutting-edge technology set in a free-to-enter Festival village in beautiful gardens.

cheltenhamfestivals.com/science
01242 850270



NORWICH SCIENCE FESTIVAL

18 – 26 OCTOBER 2019

Be inspired and intrigued at Norwich Science Festival this October! Celebrate exploration, innovation and ground-breaking research through thought-provoking talks, sensational shows and hands-on experiments at The Forum and Norwich venues.

norwichsciencefestival.co.uk
science@theforumnorwich.co.uk

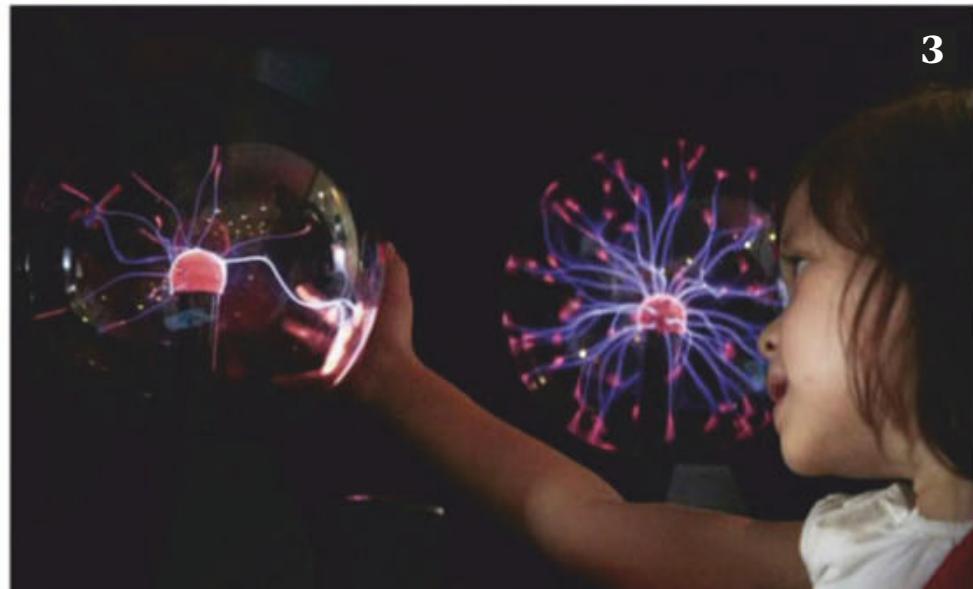


SUMMER SCIENCE EXHIBITION

1 – 7 JULY 2019

The Royal Society's annual Summer Science Exhibition offers a mind-blowing experience for anyone curious about the latest technological and scientific advances. This free, blockbuster exhibition gives visitors unparalleled access to the researchers at the frontiers of science. Discover what the city of the future could look like or simply explore the Universe, through thought-provoking talks, and entertaining performances for all ages. A special evening opening of the exhibition for adults only will be held on Tuesday 2 July. Families can explore the exhibition at their own pace during the weekend, with a dedicated children's area and exciting interactive shows.

royalsociety.org/summerscience
exhibition@royalsociety.org





PINT OF SCIENCE 20 - 22 MAY 2019

The nationwide Pint of Science festival brings incredible scientists to your local pub to show off their latest discoveries and discuss their research with you. For three nights this May you can pop to the pub and learn something new – from deep space exploration, to the rise of artificial intelligence, or the marvels of the human brain, there's something for everybody. With over 500 events from Aberdeen to York and 40 cities in between, don't miss this opportunity to pick a scientist's brain over a drink or two!

pintofscience.co.uk
contact@pintofscience.com

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isst.org / admin@isst.org
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greenman.net/tickets/



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A SCIENTIST'S GUIDE TO LIFE

SPRING CLEANING

SHOULD YOU BUST OUT THE DUSTER, OR HAVE A CUPPA INSTEAD? BEHAVIOURAL SCIENTIST **KATHLEEN VOHS** TELLS US ABOUT THE SCIENCE OF TIDINESS



SHOULD I BOTHER WITH THE SPRING CLEANING?

It depends on how much you care about the effects that cleaning can have. We've done research into this. In one study, people completed tasks in tidy or untidy rooms, then had the option to donate to charity. We found that those in tidy rooms were more generous. Cleaning seems to make you more likely to act in a way that is more upstanding and consistent with social norms.

CAN I STILL GET PSYCHOLOGICAL BENEFITS OF CLEANING IF I PAY SOMEONE ELSE TO DO IT?

Absolutely. You don't have to be the person that does all the tidying in order for your behaviour to change. A neat house can have an effect on everyone in the household.

MY TEENAGE DAUGHTER ARGUES THAT SHE CAN'T HELP BEING MESSY. SHOULD I LET HER OFF TIDYING HER ROOM?

Some people are habitually messy, but that's not always a bad thing. In another study, we had our subjects sit in clean or messy rooms while dreaming up new uses for ping pong balls. We found that people from the messy rooms were more creative and innovative with their ideas.

NOW I HAVE AN EXCUSE FOR THE STATE OF MY HOUSE. BUT WHEN SHOULD I WORRY THAT THINGS ARE TOO MESSY?

Speaking from a personal perspective, you should start to worry if the mess is interfering with your ability to get things done in an efficient manner. There's a concept called 'household chaos.' Suppose your two shoes are never in the same place. If you have to run around and find the missing shoe, it could cause problems in your everyday life. That's when things start to get too messy. The flip side is that for some people, the mental effort of keeping their shoes in one place is costlier than having to run around and find them when they are needed.

WHAT DO YOU THINK OF JAPANESE 'ORGANISING GURU' MARIE KONDO?

What I find interesting is the cultural response to her. People like her have been around for decades, but why has she been elevated to such prominence? We know from anthropology and sociology that people associate cleanliness and order with morality and ethics. So much of the world seems to be chaotic and unstructured and muddy, that I wonder if we are thirsty for something that speaks to a moral structure.

HOW DO I KNOW IF I'M TOO TIDY?

If you find you've thrown things away that you later realise you need, or if being too tidy gets in the way of enjoying social interactions. I remember going to a colleague's house that was spotless, with white carpets and a white couch, and I found that I just couldn't relax.

HOW DO I KNOW WHAT TO GET RID OF?

Try 'cleaning purgatory'. Before I throw out anything that I think I may regret, I put it in a holding bin. It sits there for a month. If I don't go back to it then it has to go. **SF**

NEED TO KNOW...

1

People with messy rooms tend to be more creative.

2

Don't let the mess take over. Household chaos can slow you down.

3

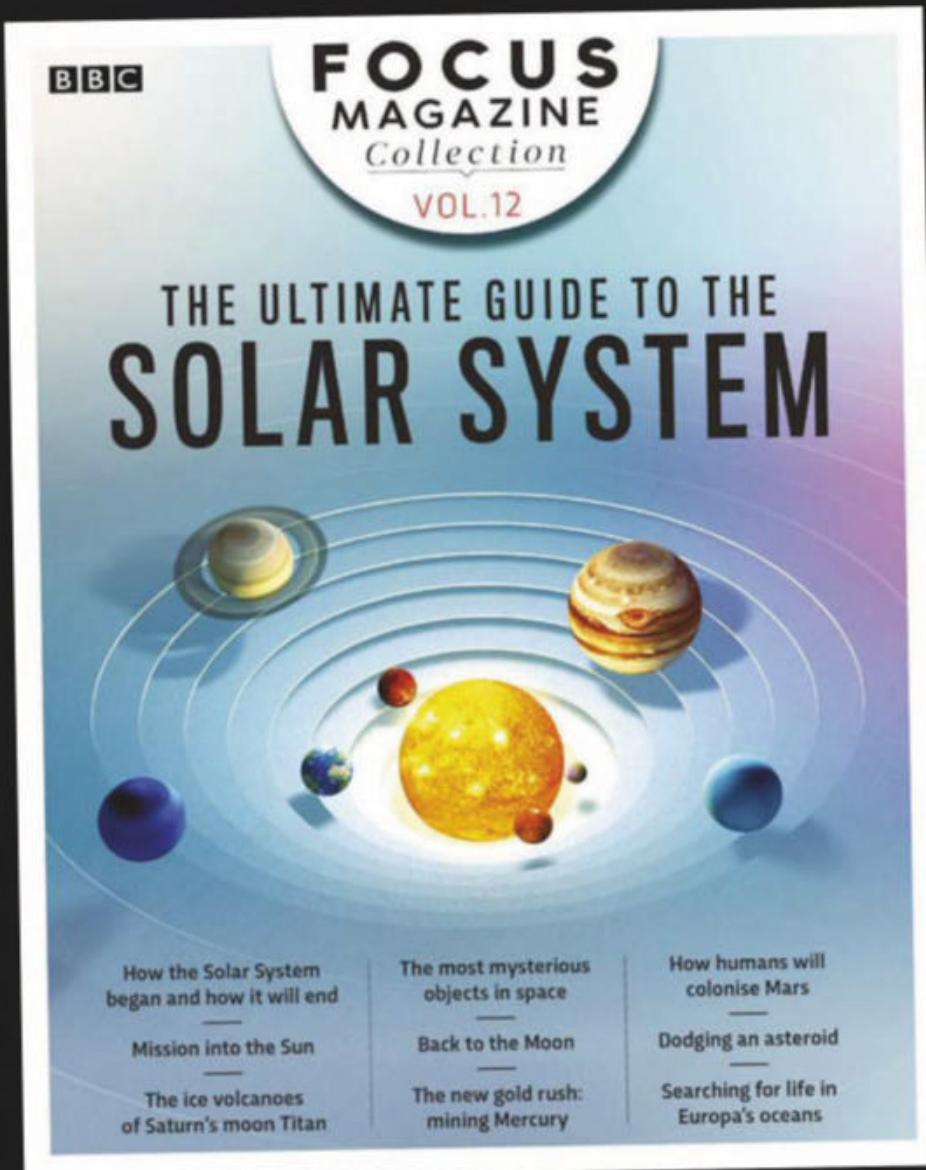
Tidiness = generosity.

KATHLEEN VOHS

Kathleen is a behavioural scientist at the University of Minnesota.

Interviewed by Dr Helen Pilcher.

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- **Searching for life** in Europa's oceans
- Mercury: our **ticket into outer space**
- The **ice volcanoes** of Titan
- The mission to **return to the Moon**
- The secrets of **dwarf planets**
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TUNE UP YOUR BRAIN

Words by RITA CARTER
Illustrations by SCOTT BALMER

Sometimes our brains just don't want to play ball. Whether it's an inability to concentrate, a tendency to forget where we left our keys, or a mental block on that final crossword clue, there are times when our minds seem to have – well – a mind of their own.

Like any machine, our brains can sometimes benefit from a tune-up. Over the following 15 pages, we look at the latest thinking around six key areas of cognition, and provide some practical, science-backed tips on how to keep your mental cogs running smoothly.

- P2** Attention
- P4** Learning
- P6** Memory
- P8** Problem-Solving
- P10** Creativity
- P12** Decision-Making
- P14** Does Brain-Training Work?
- P15** Should You Take Supplements?
- P16** The Future Of Brain-Training

1. ATTENTION

From broad beam to laser focused, it's your flexible friend

We've all experienced that irritating feeling of being distracted from the task at hand. But don't be too hard on your butterfly mind: our brains have evolved, for good reason, to be distractible. We prize an ability to concentrate, but we need our attention to be flexible. If we focused too tightly we'd miss the creaking floorboard that signifies an intruder, or the whiff of smoke that announces fire.

Attention has proven to be much more complicated, and weirder, than it seems. If you look closely at something – a photo of a landscape, say – you probably feel that you are noticing everything when, in fact, you're taking in just a few bits at a time. This is because the more you concentrate, the narrower your view becomes. Inattentional blindness, as this is known, has spawned dozens of demonstrations. The most famous is a video of a group of people passing a basketball to each other. As the passes continue, a person in a gorilla suit walks into the middle of the group and beats his chest before slowly walking off. If you show the video to people who've never seen it before and instruct them beforehand to watch the ball closely, nearly all of them fail to see the gorilla because it falls outside the laser beam of their attention.

Multitasking has also taken a knock in the lab. Recent research at Princeton University has shown that the feeling of attending to more than one thing at once is a delusion – what's actually happening is that our brains are rapidly switching back and forth from one thing to another. Even when we concentrate on a single task, our attention disengages several times a second, as our brains check that nothing important is happening elsewhere. This creates split-second gaps in our focus. When we try to multitask, these gaps tend to get so large that we

don't do any of the tasks well. That's why driving while using a phone is so dangerous.

Physically, attention is marked by neural activity in the brain areas concerned with the object of attention. If you're listening to music, for instance, neurons will be sparking in your auditory cortex (near the ears). If you're studying a picture, there will be activity in your visual brain (at the rear of the head). Areas in the parietal brain lobes (upper rear of the brain) direct attention in three-dimensional space. The more you're focusing on something, the more intense and persistent the activity. So-called gamma brainwaves, produced by neurons firing more than 25 times per second, signify intense focus, while slower brainwaves show more diffused, meandering attention.

The rear of the parietal lobe is particularly important for attention because it directs your focus, like a hand guiding the beam of a torch. Damage to this area can make a person effectively blind to whole chunks of the world – everything in the left half of their visual field, for example. Although they *can* see what's there, they don't because it doesn't attract their attention. They only see it when someone else forces them to attend to it.

But attention-related blindness is something that we all experience to a lesser degree, and it can reach into every area of our lives. People may be blithely unaware that they live in a filthy house, that someone loves or hates them, that they always wear odd socks or that their partner is cheating on them. Such ignorance may be bliss, but it can lead to disaster. Focusing on the task at hand is an important skill to learn, but sometimes it can be just as important to broaden our field of attention.



TUNE UP YOUR ATTENTION

Make a chart of your life, divided into sections such as work, family, health and so on. Go over it regularly, considering whether anything needs attention in each area. If it does, mark that section until you have done it. Aim to keep the chart clear. By looking broadly at your life, you'll be able to make sure that you're not focusing on one area to the detriment of others.

Read, watch or listen to something new every day. The unfamiliar subject matter will stimulate underused brain areas, making these brain cells easier to activate again in future, and helping to increase your overall attention.

Take short breaks from tasks that need prolonged attention. When we're doing the same thing for a long time, the brain interprets the continuous stimulus as increasingly unimportant, and becomes more prone to distraction.

Do physical exercise before doing anything that needs close attention. A study from the University of Illinois found that nine-year-olds focused better after 20 minutes of walking on a treadmill than after 20 minutes of rest. Measurements of their brain activity post-exercise showed a pattern that has previously been associated with focused attention.





2. LEARNING

Rewiring your brain the easy way – and the hard way

Learning something – whether that's new knowledge or a skill – is a physical process that actually restructures the architecture of the brain. To understand why, we need to look at what's going on in the brain when we're committing something to memory.

Every experience we have is created by the simultaneous firing of millions of neurons throughout the brain. You could imagine it as an elaborate cat's cradle of flashing fairy lights, constantly

lighting up in different combinations. Unlike fairy lights, however, when neurons 'light up' together they undergo minuscule changes that prime them to fire together in future.

Most neural firing patterns occur just once because these changes are initially very fragile. Some patterns, however, are encoded by the hippocampus – a small, horseshoe-shaped structure deep in the brain. This encourages the encoded brain activity to recur. Eventually, if a firing pattern is repeated over and over again, the neurons within it extend tendrils which link them together to form lasting pathways. The network it forms is now a permanent memory.

Events that are novel, shocking, important or painful are encoded more easily than banal ones because the neural activity involved is more intense. Encountering a flame and getting burned by it, for instance, involves fast and furious firing of visual neurons (the sight), somatosensory neurons (the feeling) and limbic neurons (the horror). A subsequent glimpse of flame then triggers activity in the whole network, including the neurons that registered the burn. This memory, even if it's not conscious, guides our response to the new situation:

TUNE UP YOUR LEARNING

Take notes and re-read them frequently. Repetition prevents information from being forgotten because it reignites and helps solidify the neural networks that hold memories. Try the Cornell note-taking method (isc.cornell.edu/notes.html):

- 1. Record the information of a lecture as notes**
- 2. Devise exam-type questions based on your notes**
- 3. Answer your questions aloud, without consulting your notes**
- 4. Reflect on your notes and your answers**
- 5. Review your older notes regularly**



Revise for an exam in a room scented with something unusual then put a bit of this scent on your wrist before the exam and sniff it if you are stuck. This is particularly effective if the material has an emotional component: in a 2011 study at Utrecht University, volunteers watched an emotionally engaging film in a room smelling of cassis (a fruity smell similar to blackcurrant). Later re-exposure to the smell triggered strong recollections of what they had seen.

Break information into chunks. For example, turn the sequence 8,3, 2, 4, 9, 0, 1, 9, 8 into 832-490-198. This makes it easier to keep in 'working memory' – the brain system that keeps new information circling in a neural repeat loop until it is used, learned, or replaced by new input. Most people can only cope with five or so 'items' in this loop. In our example, chunking effectively turns nine items into three.

instead of touching the flame, the body recoils. A lesson has been learned. Networks of linked neurons break down and build up much more easily in young brains than in older ones, which is why children learn – and forget – things so quickly.

Some things are easier to learn than others. Walking and talking, for instance, emerge without much help, provided infants see it happening around them. Natural skills like these generally emerge within specific time frames, when children's brains are genetically programmed to develop them. Newfangled skills such as reading and arithmetic, however, have to be learned deliberately, along with non-intuitive knowledge like the offside rule in football or the laws of thermodynamics. In each case, repeated practise and study will strengthen the neural networks associated with this knowledge and help commit it to memory.

Some types of learning are facilitated by so-called 'mirror neurons' – brain cells that become active in a person when they see someone else doing something. If you see someone lifting their arm, say, some of the neurons in your brain which would be involved in lifting your own arm start firing.

Mirror neurons provoke automatic mimicry, which is particularly useful for learning motor skills – a dance routine, for example, or how to serve a tennis ball.

The hippocampus not only converts experiences into knowledge, but to some extent stores this knowledge too. A famous study of London taxi drivers who had acquired a detailed mental map of the city streets found that the back part of their hippocampus was considerably larger than normal. Another important brain area for learning is the 'fusiform face area'. This patch of cortex, situated behind each ear, encodes faces, and has links to the language and emotional brain areas that generate names and feelings when you see a familiar face.

3. MEMORY

It comes in three flavours, and may betray your trust

As we saw in the previous section, learning turns experience into knowledge. But our ability to remember and recall this information at a later date is what makes this knowledge useful. And that's all down to our memory.

Our brains are very selective about what they memorise. Most experiences pass us by and fade into oblivion because there's no need to stuff our heads with memories which are unlikely to be useful.

When we *do* remember things, the system we use can be one of three types, each of which uses a different brain process. 'Working memory' uses fast-firing neurons to hold new information temporarily in mind for immediate use, short-term memory is a separate system that involves temporary changes to neural firing

patterns in the brain, while long-term memory involves permanent changes in the brain's tissue which are unlikely to disappear until the tissue itself dies or is damaged.

As we age, it gets more difficult to hold things in mind because the neurons which suppress distractions are less efficient. Meanwhile, laying down new long-term memories is more difficult because our brains are less plastic. We also find it harder to access information, even when it is well-learned. This may be because we no longer have direct pathways to it. Memory is 'state-dependent' in that it needs to be prompted by something associated with it. A retired lawyer, for example, may retain complete knowledge of their area of law but be unable to come up with it until they revisit their old office or courtroom.

Forgetting things we want to hold on to is one type of memory failure. Another is inaccurate or fabricated recall. Remembering something that happened to you is to re-experience it – up to a point. Recalling a rainy day on holiday, for example, involves activity in the sensory neurons that

TUNE UP YOUR MEMORY

Consuming lots of B vitamins (found in whole grains, seeds, nuts and beans) may help. These aid many brain functions, including neurotransmitter production. One study found that high doses of B vitamins halved the rate of brain shrinkage in people with mild memory problems. But the jury is still out on vitamin B (see p15).

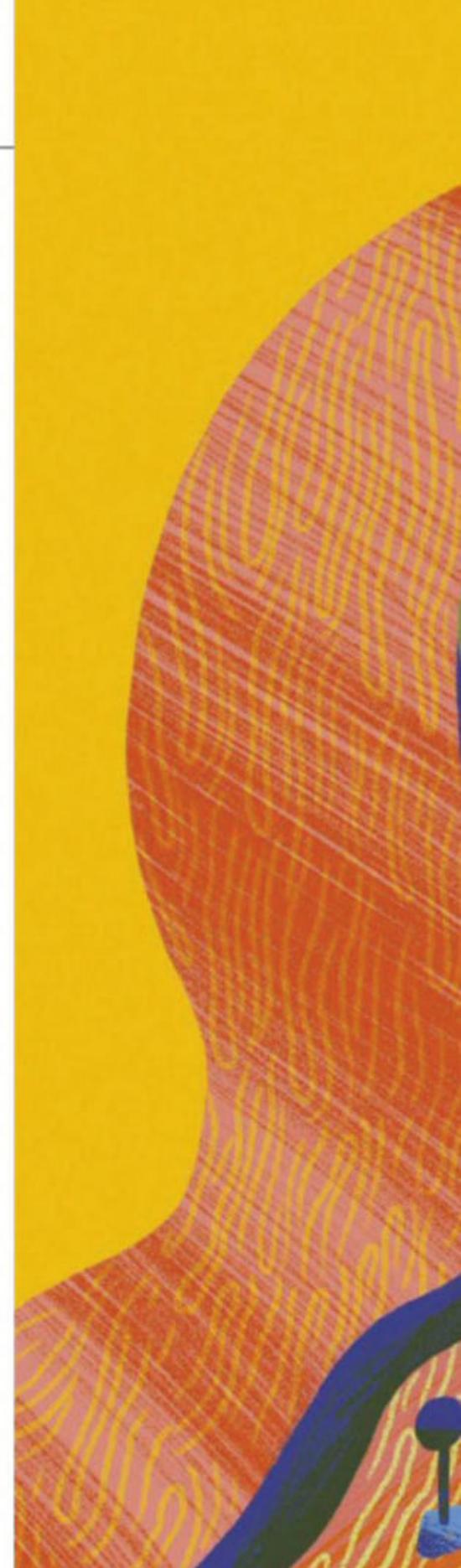
Use mnemonics such as rhymes ('30 days has September') and acronyms ('Richard Of York Gave Battle In Vain') – both tried-and-tested ways of making information more memorable.

Construct a mental picture of a familiar location, such as your home, and place things that you want to recall in its

rooms so that you can mentally stroll through the image and spot the unfamiliar items you've stored there – a bit like Sherlock's 'mind palace'.

Write a to-do list each morning and consult it at regularly throughout the day, to keep it fresh in your mind..

Establish habits such as putting your keys on a particular hook every time you come in. This establishes a link in your brain between the objects (e.g. the hook and the keys), so that when you need your keys you automatically remember the hook, rather than trying to recall, each time, where you put them last.





originally produced the feel of the water droplets and the sight of the cloudy landscape, together with those that produced an emotion (disappointment, maybe, at not being able to enjoy the beach). Neurons that registered the faces of the people you were with might fire again, together with those triggered by the food you were eating.

While this brain activity is similar to the patterns that occurred at the time, it is never identical. Even when we're thinking about the past, our brain is keeping tabs on the present, so our neurons are being stimulated not only by the memory, but also by the sounds, sights and smells around us. The patterns are fused together, so every time we recall a memory, we add something of the present moment. Eating a pizza while recalling that rainy day, for instance, might cause the pizza to enter the memory, so that next time you might remember eating a *quattro formaggio* as that holiday rain fell.

Memory distortions like this are inevitable, and sometimes dangerous. Several decades ago, psychologist Elizabeth Loftus demonstrated that false memories can be planted in people's

minds with astonishing ease. Now, researchers have discovered a new twist: 'choice blindness'. This refers to people's failure to notice when their own statements are falsified. It has huge implications for criminal law, which depends on witness reports. In a 2016 study at the University of California, volunteers identified the culprit of a staged crime from a line-up. Two days later they were invited to confirm their choice but, unknown to them, were presented with a photo of a different person. Two-thirds of the volunteers agreed this was the culprit they had first identified.

So it's clear that memory is a fickle creature, and that we should take our recollections with a pinch of salt.

4. PROBLEM-SOLVING

When brute-force intellect fails, expand your mind

Solving problems draws on two types of intelligence: crystal and fluid. Crystal intelligence involves using stored knowledge to answer questions of fact (e.g. what is the speed of light?), which in turn relies on our ability to learn and remember information.

Fluid intelligence involves solving more creative problems, such as how to get a lion, a goat and a cabbage over a river in a single-passenger boat. This kind of intelligence has proven more difficult to get to grips with, partly because solutions tend to pop, fully formed, into consciousness as “aha!” moments, and no amount of introspection reveals the cognitive processes that led to them. It also seems that our brains use different strategies for different types of puzzle.

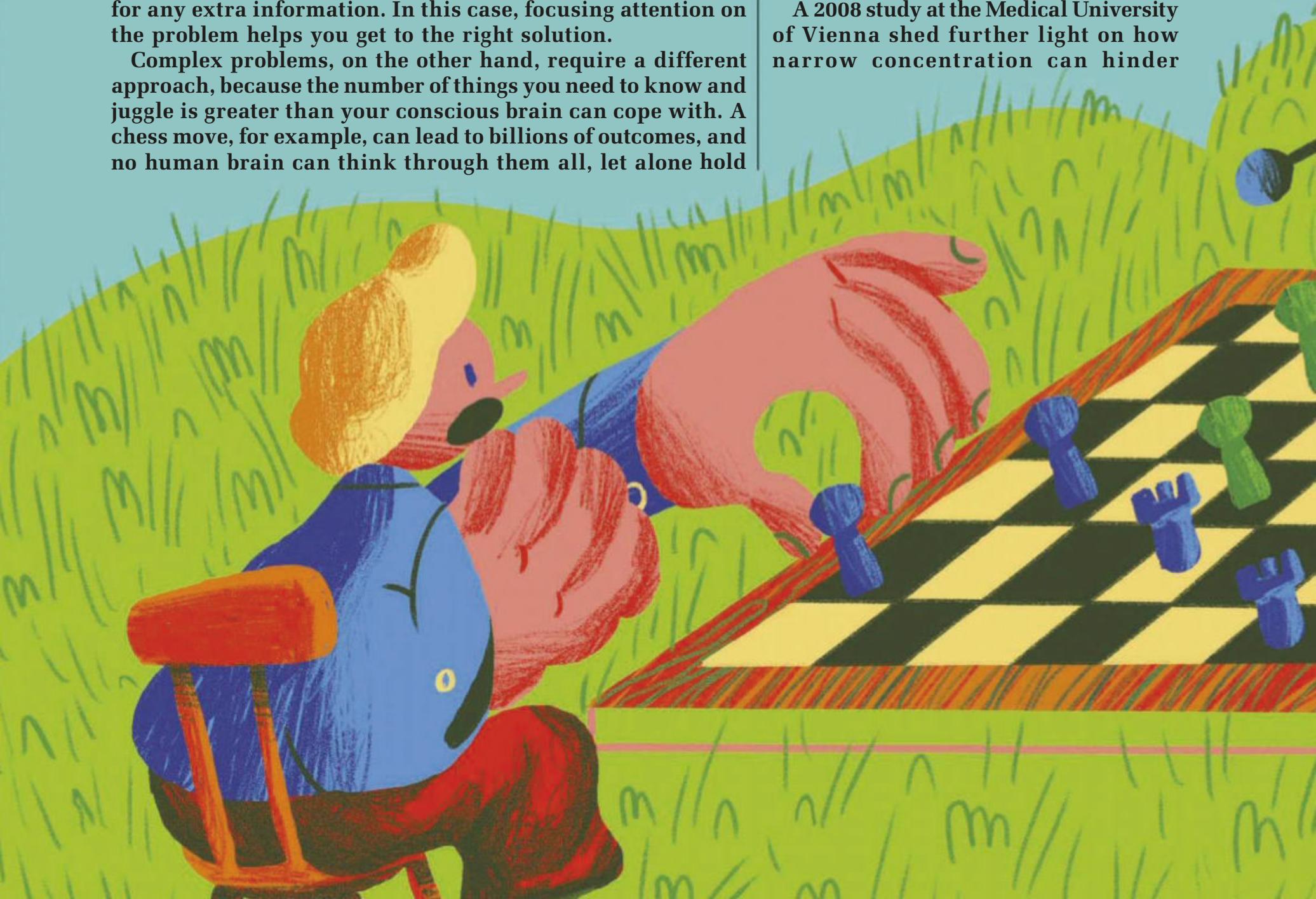
We tend to work out simple problems – those involving just a few factors – methodically. For example, to solve “If $ABC = 123$, then $DEF = ?$ ” you need to know three things: the alphabet, the number sequence, and the coding technique of linking two sequences in parallel. Once you have this knowledge, you can find the answer by matching letters to their appropriate numbers, without having to look elsewhere for any extra information. In this case, focusing attention on the problem helps you get to the right solution.

Complex problems, on the other hand, require a different approach, because the number of things you need to know and juggle is greater than your conscious brain can cope with. A chess move, for example, can lead to billions of outcomes, and no human brain can think through them all, let alone hold

them in mind simultaneously in order to compare them. Inexperienced chess players typically react to the complexity of a chess problem by concentrating hard on working out possible sequences of events. Rather than helping them, however, this intense, narrow attention can make their play worse.

The reason is that focusing attention on sequential computation, which is done by the brain’s left hemisphere, closes down areas of the right hemisphere that are concerned with taking a wider view. Master players, by contrast, use their right hemispheres as well as their left. The right-hemisphere activity produces an intuitive sense of the gist of the problem and provides context for the conscious computations occurring in their left hemisphere. This use of intuition, when honed by years of experience, distinguishes experts from novices not only in chess, but also in every area that requires complex problem-solving.

A 2008 study at the Medical University of Vienna shed further light on how narrow concentration can hinder



problem-solving. By monitoring volunteers' brainwaves as they struggled to solve a word puzzle, the researchers found that intense attention locks the brain into a particular pattern of activity, producing cognitive tunnel vision. Low-level attention, in contrast, allows neural patterns to change, making it easier to incorporate new information. It's the difference between trying to work out what an object is by staring at it from a single perspective, or ambling around it, receptive to anything that might give guidance.

As well as looking at a problem from multiple angles, brilliant problem-solving involves dismissing bad options quickly, before they can use up limited cognitive resources. This ability has recently been introduced to artificial intelligence, producing machines that for the first time are able to beat the best human players at Go, an ancient Chinese strategy game. This 'self-learning' type of AI can rehearse its strategies, note those which don't work, and feed the information back into the system, tagged with an instruction to avoid them in future. In the human brain, a similar process is executed by an area called the anterior cingulate cortex (ACC). This tiny bit of tissue, tucked into the deep fold that divides the two hemispheres, probably did more than any other brain region to make humans the best problem-solvers on Earth. Until now, perhaps.



TUNE UP YOUR PROBLEM-SOLVING

Challenge yourself with increasingly complicated problems. Eventually your brain will learn to abandon the fixed-attention strategy it uses for simple problems, and start to look at problems from multiple points of view.

If you're stuck on a puzzle, shift attention elsewhere and come back to it later. This turns off the neural firing pattern that is locking the brain into an unsuccessful approach, and allows the brain to incubate the problem, casting around unconsciously for knowledge that might be useful. When you return to the puzzle, this new information is likely to be incorporated into the problem-solving attempt.

Combine problem-solving with a low-level activity such as walking or jogging. This helps to reduce focused attention because you need to use some of your conscious resources on the activity you're performing. It also increases blood flow and endorphin release, which perks up brain cells just as it does cells in other parts of the body.

Brainstorm privately. Complex problems often require left-field solutions, so thinking far and wide, in areas which do not immediately seem relevant, can help broaden your perspective. The dFTER the ideas you allow yourself to come up with, the freer your brain will be to stumble upon a solution.



5. CREATIVITY

The recipe? An elusive blend of focus and relaxation

Human creativity has long been something of an enigma, but a fortuitous discovery led to a breakthrough in our understanding of this slippery subject.

Most brain studies have involved asking volunteers to perform tasks – matching words, say, or doing calculations – while their brains are monitored by some sort of imaging technology. This has allowed scientists to build up detailed

'maps' of what is happening when we're doing things. For many years, however, no one thought to look at what happens in our brains when we're *not* doing things. As luck would have it, there was plenty of data to hand because most brain studies involved rest periods whereby volunteers were told to relax and think of nothing in particular. Their brain activity in this state was usually recorded along with the active phases, but ignored.

Eventually, by chance, it was noticed that the brain activity seen in 'no-thought' states was similar in practically everyone. The pattern was named the default mode network (DMN), and it has turned out to be the key to human creativity.

The DMN is the opposite of another electrical pattern known as the executive control network (ECN), which lights up when we're in a 'doing' state. In the ECN,



the brain's neurons fire rapidly, but in relatively few areas. This is goal-directed activity, and it locks the brain into focused thinking. When a person stops pursuing a particular goal, however, their brain activity switches to the DMN, marked by low activity in a large and diffuse collection of brain areas. This state feels relaxed and free-ranging. The thoughts that arise tend to revolve around the individual, and involve past and imagined social scenarios. A person might, for instance, recall a conversation from earlier that day, or rehearse what they will say to someone they are due to meet later.

In the DMN, imagination comes to the fore. Because the brain is unshackled from the need to form and execute a particular action plan, it's able to try out lots of different ideas, imagining and comparing their outcomes. It also allows thoughts and memories to link up temporarily in unusual ways, creating an internal, near-surreal kaleidoscope in which fish may fly and pigs may talk.

Imagination is not the same as creativity, however. A brain that is completely unharnessed may throw up wildly imaginative ideas, but they may merely seem unhinged. To be creative, ideas need to be useful (e.g. a better mousetrap) or wrapped in talent (e.g. a Dalí painting). So to harness the output from the DMN, the brain has to fire up the ECN, or at least part of it.

Usually, activation of the ECN automatically turns off the DMN, and vice versa – we flip-flop from one state to the other. Research suggests, however, that creative people are able to activate both networks at once. In a study last year, people's brains were scanned while they tried to think of imaginative uses for a sock, for soap and for a chewing gum wrapper. Some volunteers just couldn't do the task: they could only think of things like "covering the feet", "making bubbles" and "containing gum". Other volunteers suggested a water filtration system, a seal for envelopes, and an antenna wire. These creative thinkers, unlike the others, were found to be activating both the DMN and parts of the ECN simultaneously.

Can you learn to get this particular neural pattern going? So far, no one has put it directly to the test. However, brain activity is habitual, like the behaviour it produces, and if you sense a lack of creativity in yourself, you can encourage it to grow.

TUNE UP YOUR CREATIVITY

Look out of the window when you're next on public transport instead of using your phone. Studies have shown that daydreaming and boredom can allow the mind to wander, helping to foster creativity.

Cut up pages of a newspaper and rearrange the words to make grammatically correct nonsense statements. By keeping the words within the structure of grammar, the new sentences keep some kind of meaning, forcing the brain to look at the content in a new way – a handy skill for creative thinking.



Turn down the lights: a 2013 study by psychologists at the Universities of Stuttgart and Hohenheim in Germany found that dim lighting can improve creativity. Darkness, they say, creates a feeling of freedom, triggering "a risky, explorative processing style".

If you're reading a story, stop the narrative mid-flow and think of five different possible endings.

Transform your current visual experience into something odd. For example, imagine all the objects around you turned upside-down. Can you see a new use for any of them in this state?

Interrupt a daydream by trying to think of some way to use it in real life, perhaps by polishing it into a story, or a party anecdote.

6. DECISION-MAKING

So-called free will and the emotionally fraught business of choice



Every decision we make is arrived at through hugely complex neurological processing. Although it *feels* as though you have a choice, the action that you 'decide' to take is entirely dictated by automatic neural activity. Brain imaging studies show that a person's action can be predicted by their brain activity up to 10 seconds before they themselves become aware they are going to act.

This has huge implications for our concept of free will, which scientists and philosophers are still grappling with today. Multiple neuroscientific studies show that even those important decisions that feel worked out are just as automatic as knee-jerk reactions (although more complex). The sense of volition seems to be a clever illusion perpetrated by our brains, and the illusion is useful because it gives us a sense of responsibility – and causes us to moderate our behaviour accordingly.

Decision-making starts with the amygdala: a set of two almond-shaped nuclei buried deep within the brain, which generate emotion. The amygdala registers the information streaming in through our senses and responds to it in a split second, sending signals throughout the brain. These produce an urge to run, fight, freeze or grab, according to how the amygdala values various stimuli.

Before we act on the amygdala's signals, however, the information is usually processed by more sophisticated brain areas, including some that produce conscious thoughts and emotions. Areas concerned with recognition work out what's going on, those concerned with memory compare it with previous experiences, and those concerned with reasoning, judging and planning get to work on constructing various action plans. The best plan – if we are lucky – is then selected and executed. If any of this process goes wrong, we are likely to dither, or do something silly.

The various stages of decision-making are marked by different types of brain activity. Fast (gamma) waves, with frequencies of 25 to 100 Hz, produce a keen awareness of the multiple factors that need to be taken into account to arrive at a decision. If you are trying to choose a sandwich, for



instance, gamma waves generated in various cells within the 'taste' area of the brain bring to mind and compare the taste of ham, hummus, wholemeal, sourdough, and so on. Although it may seem useful to be aware of the full range of choices, too much information makes decision-making more difficult, so irrelevant factors get dismissed quickly and unconsciously. At the sandwich counter, the cheese and tomato option might trigger only the tiniest flurry of neuronal excitement.

After this surge of activity marking the comparison stage, the brain switches to slow-wave activity (12 to 30 Hz). This extinguishes most of the gamma activity, leaving just a single 'hotspot' of gamma waves which marks the chosen option.



Although there is no 'you' outside your brain to direct what it's doing, you can help it to make good decisions by placing yourself in a situation which is likely to make the process run more smoothly. Doing something that is physically or mentally stimulating before making a decision will help your brain produce the initial gamma waves that generate awareness of the competing options. Getting over-excited, on the other hand, will prevent the switch to the slow brainwaves, making it much harder to single out a choice. Subjecting yourself to high emotion may also warm up the connecting pathways from the amygdala to the action areas of your brain, causing panicky or impulsive behaviour.

TUNE UP YOUR DECISION-MAKING

Make a list of your bad decisions and look for links. Were they all compromises, for example, or made hastily? When you identify a link, analyse the mental strategy that you used, and try deliberately using the opposite strategy for a while. If the problem seems to be haste, for example, delay the decision, and be ready to acknowledge any vaguer, subtler factors that come to mind.

Brainstorm before a decision, then sleep on it before acting. Like creative thought, good decision-making benefits from unconscious incubation, in which the brain drifts around, rummaging through memories that might be useful. Sleep is an extreme case of incubation, and your dreams may throw up important clues that make your decision clearer upon waking.

Mentally step back from the situation and ask yourself what others might do. This will force your brain to look at the situation from a new perspective, which may reveal factors you had not previously taken into account.

Write down your favoured option, then highlight the emotional words. If you delete the highlighted words, is the decision still looking good? If not, these words are your real reasons for the decision. 'Attractive' or 'exciting' may be valid factors in deciding on a date, but not so good if you're choosing an accountant.



7. DOES BRAIN-TRAINING WORK?

The verdict on games, crosswords and other ‘brain-boosting’ exercises

The brain is like a dense conglomerate of muscles, each one dedicated to a particular task. Exercise any one of them and it will get stronger, but you need to exercise them all to improve your general cognitive ability. If you practise adding up figures all day, for instance, you will get very good

at adding up figures, but if you never resort to estimation – a skill performed by an entirely different brain ‘muscle’ from arithmetic – you will be no better than anyone else at judging, say, the size of a crowd.

Brain-training has been dogged by the difficulty of developing exercises that improve functioning across the brain rather than in one small part. It’s now recognised that suites of exercises – those that package together visual search exercises with motor coordination challenges and word-retrieval games, for instance – can have broad benefits. However, if you have a healthy brain capable of a normal range of skills, the best exercise you can get is real life. Taking an active part in the community, enjoying art, listening to music, engaging politically and enjoying a rich social life – these are the best training of all.

Not all of us, however, have optimally healthy brains. Nor is it always possible to develop or practise the full range of cognitive skills. Brains degenerate physically with age, just like every other part of the body, and many people can’t live



life to the full because they're locked into repetitive work or cut off for some reason from intellectual stimulation.

When people get older, their neurons tend to be less excited by environmental stimuli. This is partly due to reduced hormones and neurotransmitters, but partly because fewer events are novel and stimulating. Our brains have 'been there, done that', and are not inclined to use too much energy doing it again. Just as brain activity primes the brain to activate in the same way again, subdued brain activity *reduces* future activity. So, whether you go for computer gaming, reading, listening to music or playing sport, the first thing brain exercise should do is get you excited.

The second thing it needs to do is to work as many cognitive muscles as possible. Crosswords are the famous go-to exercise because they involve several elements of cognition: memory, problem-solving, and spatial sensitivity (noticing how the words fit together). If you do crosswords too often, however, you may get so good at them that they no longer stretch you. The person who boasts that they complete a broadsheet cryptic puzzle every day may be doing less for their brain than someone who struggles to solve a single clue in a much simpler puzzle.

The same is true of Sudoku. The numbers game can be very challenging, especially for newcomers, but doing Sudoku every day merely makes you better at Sudoku – a skill that is quite difficult to find a use for elsewhere.



SHOULD YOU TAKE SUPPLEMENTS?

A varied diet should provide all the brain-healthy nutrients you need, but could you benefit from taking more of them? Omega-3 – the fatty acids found in fish such as herrings, sardines and mackerel – is the supplement best known as a brain-booster. But the evidence for its effects is underwhelming. A 2012 review by the Cochrane organisation – widely acknowledged as an authority on health research – found no evidence that omega-3 reduces the risk of cognitive impairment, while a 2015 meta-analysis by Canadian scientists concluded: "Omega-3 fatty acids, B vitamins, and vitamin E supplementation did not affect cognition in non-demented middle-aged and older adults."

Similarly, evidence for the herbal supplements ginseng and ginkgo biloba fails to stand up to scrutiny. The same goes for practically every other so-called brain-booster. The Natural Medicines Comprehensive Database, a non-commercial organisation that continuously collects and reviews data, failed to find a single proven effective supplement among more than 50 they assessed. They rated a few as "possibly effective" but most simply had "insufficient evidence" to make a judgment.

Lack of proof of efficacy is not, however, proof of lack of efficacy. The large-scale, expensive research needed to show beyond doubt whether something works is usually done only for medicinal drugs, so it's not surprising that there's no concrete evidence for the effects of supplements in healthy people.

Supplements are not without risk – they can interfere with medicines and produce nasty side effects, especially if too many are taken. However, a supplement that gives the recommended daily dose of required vitamins and minerals may be a good idea if you feel your brain needs a boost, especially if you think your diet may be deficient in some way. Just consult your doctor if you experience any side effects.



8. THE FUTURE OF BRAIN-TRAINING

Can electrical stimulation and ‘smart drugs’ boost brainpower?

BRAIN ZAPPERS

Strapping electrodes to your skull to stimulate your brain with a buzz of electricity might sound scary, but done properly, non-invasive ‘transcranial direct-current stimulation’ (tDCS) is safe – it uses a minute charge and feels tingly but not painful. tDCS is extremely well-researched – it features in more than 2,000 studies published in mainstream academic literature – and has been found safe and tolerable, even for children.

So would you benefit from tDCS? Many studies have found that it improves a wide variety of cognitive skills, and helps relieve mood disorders such as depression, but there are some studies that show minimal or no benefit. Generally, around 10 to 20 minutes of tDCS a day seems to have modest, cumulative effects. Most studies have been conducted on people with brain problems, however, so results can’t always be applied reliably to those with healthy brains.

Another thing to bear in mind is that the effect of tDCS depends on where the electrodes are placed on the head. There is a ‘sweet spot’ (the dorsolateral prefrontal cortex) which tends to be the default option because it has positive effects on mood, memory and cognition. Other benefits require different placements. Some tDCS devices come with a ‘map’ of electrode locations.

There are dozens of DIY devices on the market – established makes include foc.us and TheBrainDriver. To date, there are no legal barriers to the direct-to-consumer sale of tDCS devices, but do your research before buying. Some are expensive machines aimed at research, which include features that are



unnecessary for home use. At the other end of the spectrum, the cheapest, home-made tDCS devices may not have reliable timing mechanisms or adequate safety measures, such as an automatic cut-out in the event of an electricity surge. There is limited independent research on how well consumer tDCS devices work, however.

CHEMICAL AGENTS

‘Smart drugs’ is an umbrella term for hundreds of substances claimed to boost brainpower. About 12 per cent of university students are thought to use smart drugs in the hope of improving their performance, with many available to buy easily online.

Also known as ‘nootropics’, these include some prescription drugs such as Ritalin and Adderall, which are licenced for attention-deficit disorders, and modafinil, a treatment for narcolepsy. These have proven benefits for patients, but whether they work for healthy people is less clear. And they can have adverse effects, so you would be unwise to take them without advice from your GP.

Smart drugs also include herbal supplements, which may claim plenty of proof of efficacy, but have not been put through the rigorous trials needed for prescription medication. SF

by RITA CARTER

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